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ZOOLOGY.

VOL. XXXIII.

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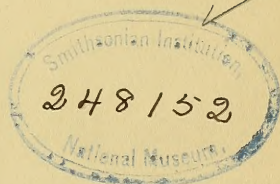
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- 11, line 15, for *Caliaeschna* read *Calliaeschna*.
 25 „ 10, for *Macronia* read *Macromia*.
 226, lines 1 and 2. Section 3 and Experiment 494 are deferred publication.
 240, line 4, *Acræinæ* should be *Acræinæ*.
 249 „ 20, read butterflies.
 256 „ 27, for *cloantha* read *cloanthe*.
 270 „ 4 from bottom, for *perpicua* read *perspicua*.
 290 „ 25, read *Vernonia Livingstoniana*.
 300 „ 3 „ *Charaxes neanthes*, *Catopsilia florel*
 304 „ 31, for *Pinacopteryx* read *Glutophrissa*.
 305 „ 26, for *P.* read *G.*
 323 „ 4 from bottom, read *Catochrysops*.
-

Mr. Swynnerton's paper, pages 203-385, has necessarily suffered from having to be printed from his notes which had not been specially revised for the printers, and during his absence from England. Dr. G. A. K. Marshall has very kindly read the proof against the manuscript and supplied those authorities which were wanting in the original

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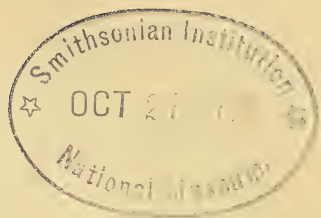
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(ZOOLOGY.)



Life-Histories and Descriptions of Australian *Æschninae*; with a Description of a New Form of *Telephlebia* by HERBERT CAMPION. By R. J. TILLYARD, M.A., F.E.S., Science Research Student in the University of Sydney. (Communicated by Prof. W. A. HASWELL, F.R.S., F.L.S.)

(PLATES 1-9, and 4 Text-figures.)

[Read 18th June, 1914.]

THE present paper is not designed to be a complete monograph of the Australian *Æschninae*, on the lines of E. M. Walker's excellent work on the genus *Æschna* in North America *. To deal with the whole subfamily in Australia on such lines would not only have involved the production of a paper far beyond the bounds of the present one in cost and size, but would have unnecessarily duplicated much good work already accomplished. Most of the Australian species have been already well described by René Martin †, while a few have been added by Förster and myself. But so far nothing has been published on their life-histories, nor has any attempt been made to survey their geographical distribution and their phylogeny (except in so far as the Australian forms have entered into the *general* discussion of these problems for the whole subfamily). It has been mainly with these three objects in view that I have been collecting material for the present paper

* Univ. of Toronto Studies, No. 11, 1912.

† "Les Odonates du continent australien," *Mém. Soc. Zool. France*, xix. (1901) p. 220.

during the last five or six years. New species have been described in shorter papers as they came along ; but there still remain some interesting additions, which find a place here.

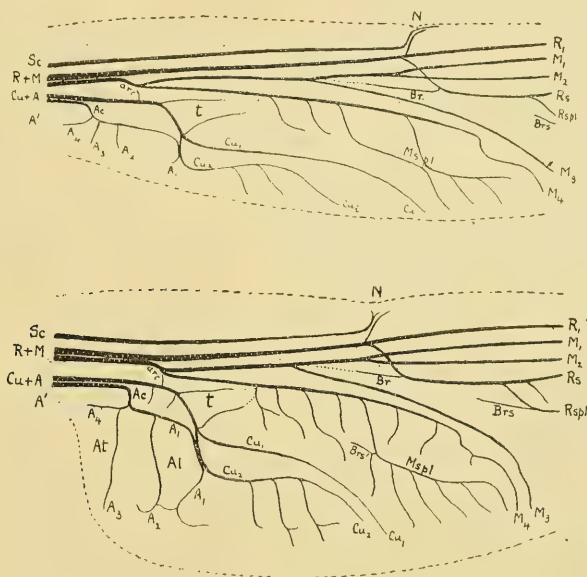
The material studied is almost wholly in my own collection, or has been there at some time, many of the specimens having been sent out to various correspondents. Nearly all the specimens have been collected by myself ; but I must not minimize the importance of consignments sent to me by several generous correspondents from various parts of Australia. These, though small in number, have often contained rare species which I myself could not obtain. A complete list is given in an appendix, the name of the sender being given in brackets in each case. In this connection, I desire to acknowledge the generous help which I have received from Dr. A. J. Turner, the late Mr. H. Elgner, and Messrs. E. Allen, S. Angel, G. F. Berthoud, H. J. Carter, F. P. Dodd, C. Goldfinch, H. Hacker, G. Iyell, E. A. C. Olive, and G. A. Waterhouse. I also desire to thank Dr. R. Hamlyn-Harris, Director of the Queensland Museum, and Mr. Robert Hall, Curator of the Hobart Museum, for allowing me the opportunity of studying two unique specimens. Finally, for valuable help in the preparation of photographs, and for much useful advice on the same, I am indebted to Miss M. Reinhold, Dr. F. Ris, and Mr. F. W. Carpenter.

The headquarters of the Australian *Æschnine* are undoubtedly the mountain fastnesses of the South-East, with their extensions northwards through New South Wales and Queensland, mostly close to and parallel to the coast-line. Many of the species may be considered sub-alpine, being found up to the 5000-foot level, and possibly higher. They exhibit a variety of form and coloration far greater than that found in similar groups in other regions. In particular, the species that inhabit the coldest climates exhibit the most brilliant colouring ; while a very distinct tendency towards a general darkening, both of ground-colour and markings, is noticeable in the more northern forms. The number of known species (twenty-six) bears a greater proportion to the total number of Australian Odonata than might be expected from the small size of the subfamily. This is wholly due to the magnificent development of the autochthonous genus *Austroaeschma* and its allies.

Before entering on the main portion of this paper, I have to indicate what is, to my mind, a very necessary alteration in the accepted Comstock-Needham notation for the wing-venation of this group. On page 721 of his now famous paper* Professor J. B. Needham notes the fact that, in all the larval wings of *Anisoptera* examined by him, trachea *A* joins trachea *Cu* close to the base, and runs along with it for some distance before branching off downwards. I have found the same thing to occur in all the Anisopterid

* "A Genealogic Study of Dragonfly Wing-Venation," Proc. U.S. Nat. Mus. xxvi. (1903) p. 703.

larvæ which I have examined. Needham, however, after noting the fact, is content to allow the notation of the imaginal venation to remain in such a state that the true origin of the so-called anal vein of the imaginal wing is obscured. In my studies on the anal trachea of *Anisoptera**, undertaken mainly with the view of determining the phylogenetic development of the anal loop, I was impressed with the great importance of a correct naming for the veins that arise around the tracheæ of this part of the wing. To make the point quite clear, I give herewith figures of the tracheation of the wings of a nearly full-grown larva of *Æschna brevistyla*, Ramb. (figs. 1 & 2). In



FIGS. 1 & 2.—Fore and hind wing-cases of nearly full-grown nymph of *Æschna brevistyla*, Ramb., to show tracheation. Permanent venation omitted, except for continuations of *A'*, *Br*, and sides of *t*.

Tracheæ:—*A*, anal; *A'*, *A*₁, *A*₂, *A*₃, its branches; *Ac*, anal crossing; *arc*, arcus; *Br*, bridge from *Rs*; *Brs*, bridge from *Rspl*; *Brs'*, bridge from *Mspl*; *Cu*, cubitus; *Cu*₁, *Cu*₂, its branches; *M*, mediana; *M*₁, *M*₂, *M*₃, *M*₄, its branches; *Mspl*, median supplement; *N*, nodus; *R*, radius; *R*₁, its upper branch; *Rs*, radial sector; *Rspl*, radial supplement; *Sc*, subcosta.

Spaces:—*Al*, anal loop; *At*, anal triangle; *t*, triangle.

these, as in all Anisopterid nymphal wings examined by me, trachea *A* joins trachea *Cu* very close to its origin, in the same manner that *M* joins *R*. Then *Cu* and *A* run along together as far as the future first cubito-anal cross-vein. At this point, *A* bends sharply downwards away from *Cu*,

* The results of this study will shortly be published.

exactly as M bends away from R at the arculus. This portion of A I have designed the "anal crossing" (Ac). It is at this point that the future "first cubito-anal" cross-vein is laid down, and its persistency in all forms is a necessity, since it is a part of the true anal trunk.

At the posterior end of Ac , A branches into two (sometimes three). One branch, A_4 , runs back basad parallel to $Cu + A$ above it, but not very far. Along the course of this trachea the vein called "anal" by Needham is laid down as a kind of bridge-vein connecting to the *posterior border* of the true wing-base, and forming the attachment for a special *rotator* muscle. This vein is, strictly speaking, not A at all, but the *secondary anal vein*, A' .

We thus see that Needham's Cu is really $Cu + A$ as far as Ac , while his A is really A' .

From A_4 , very close to its origin from Ac , a strong trachea A_3 descends towards the wing-border (in some forms A_3 descends directly from Ac).

The second branch of A from Ac runs distad, giving off a branch A_2 not far from Ac , and then running on, as A_1 , to meet Cu_2 near its point of bifurcation from Cu_1 . It then joins Cu_2 for a short distance, and finally breaks away from it again and curves inwards basad. Hence the *anal loop* of the *Æschninæ* is enclosed between A_2 and A_1 entirely. Needham has correctly determined these parts for the *Æschninæ*, but not for the other subfamilies.

In fig. 3 I give the amended nomenclature on a diagram of the wings of *Æschna brevistyla*. The necessity of the alteration will be at once seen by comparison of the adult venation with the nymphal tracheation.

As regards the life-histories many gaps still remain, and the field for observation of small but interesting and often very important points is almost unlimited, and open to any earnest field-worker to follow up. These large Dragonflies are the most difficult of all to study, owing to the great rarity of most species, their rapidity of flight, and their shyness. The student of the *Æschninæ* must have an unlimited supply of patience, and must be content to add, year by year, only a fact here and a fact there, until he approximates to a full knowledge of each particular case. I have fortunately been able to discover larvæ representative of every genus in Australia, with the single exception of *Austrogynacantha*; but only in very few cases can I give at all a complete account of the life-history.

During the course of my studies on this group, I have been particularly struck with the close agreement between the accepted phylogeny of the *Æschninæ* and their present geographical distribution (in the case of the Australian forms). I have, therefore, adopted the somewhat novel, but I hope fully justified, expedient of subdividing them into geographical groups based on their present distribution in relationship to the continent of Australia. This subdivision will be found to correspond exactly with the accepted phylogenetic classification. For convenience of reference, I have

divided the subfamily into tribes, which I have named. In the main, I find myself in agreement with the work already carried out by others, especially as regards the latest arrangement suggested by Walker.

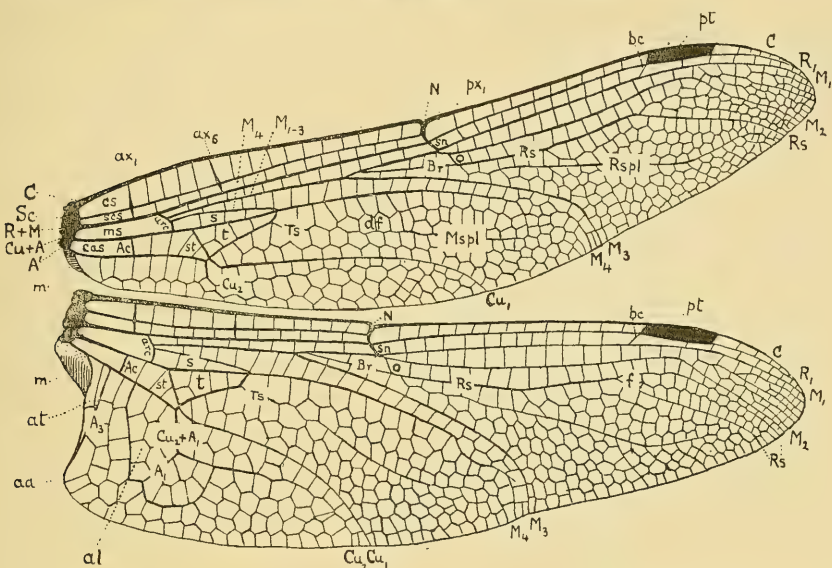


FIG. 3.—Wings of *Aeschna brevistyla*, Ramb., ♂, to show new notation.

A, anal vein; *A*₁, *A*₂, *A*₃, its branches; *Ac*, anal crossing, or first postcubital; *A'*, secondary anal vein; *aa*, anal angle; *al*, anal loop; *arc*, arcus; *at*, anal triangle; *ax*₁, *ax*₆, first and sixth antenodals, thickened; *bc*, brace-vein; *Br*, bridge; *C*, costa; *cas*, cubito-anal or submedian space; *cs*, costal space; *Cu*, cubitus; *Cu*₁, *Cu*₂, its branches; *df*, discoidal field; *M*, median vein; *M*₁, *M*₂, *M*₃, *M*₄, its branches: *M*₁₋₃ upper, *M*₄ lower sector of arcus; *Mspl*, median supplement; *m*, membranule; *ms*, median or basilar space; *N*, nodus; *O*, oblique vein; *pt*, pterostigma; *px*, first postnodal; *R*, radius; *R*₁, its upper branch; *Rs*, radial sector; *Rspl*, radial supplement; *s*, supertriangle, or hypertrigonal space; *scs*, subcostal space; *Sc*, subcosta; *Sn*, subnodus; *st*, subtriangle; *t*, triangle; *Ts*, trigonal supplement.

General Characters of the Subfamily.

IMAGINES.—The *Æschninae* are the large swift-flying Dragonflies that are so often seen hawking about, sometimes far from water, and more especially in the afternoon and early evening. Their colour-scheme varies from dull browns and blacks to beautiful patterns of green, blue, or yellow on a dark ground. Bright blues and reds, and metallic colourings, such as are met with in the Libellulidæ, are absent in this group. With the exception of the *Petaliini*, which I have included in the subfamily on good grounds, but which nevertheless depart considerably from the generally accepted idea of

an *Æschnine*, the following characters may be said to be common to them all :—

Venation.—Triangles elongate, crossed, of approximately equal shape and size in both wings ; basal side always considerably distal from arculus. Antenodals of first and second series not corresponding, except two specially thickened ones (usually the first, and another between the fourth and eighth). M_2 always arching up more or less under the pterostigma, so as to approach M_1 . Pterostigma nearly always long, generally narrow, usually braced. Strong supplements developed under R_s and M_4 . Membranule very seldom absent. Anal border of hind-wing of male angulated (except in *Anax*). Anal loop short and fairly broad, never elongated.

Head.—Eyes very large, touching for a considerable distance ; consequently postocular region much reduced to a small triangle or tubercle, and vertex reduced to a vesicle or tubercle. Antennæ short, with two short, rather stout, basal joints, followed by five slender filiform joints. Front, face, and mouth-parts well developed ; labium hairy, with broad lateral lobes carrying movable hooks, and short wide mentum.

Thorax.—Prothorax very small, often reduced to a mere neck and a small basal support for the fore-legs. Meso- and metathorax firmly united together, strongly built ; rostrum with very distinct but small scuta and scutella. Legs strong, fairly large.

Abdomen.—Always slender and elongated, never either clubbed or swollen towards tip. Auricles present on segment 2 of male (except *Anax*). Accessory genitalia of segment 2 of male lodged in a deep median ventral depression or fossa. Male with two superior and one inferior anal appendages. Female with generalized ovipositor suited for placing eggs in the tissues of plants, and consisting of three pairs of elongate processes, one pair developed from the eighth, the other two from the ninth sternite.

LARVA or *NYMPH*.—*General shape* elongate, with large head, prominent eyes supported by strong postocular lobes ; prothorax of moderate or small size, often with lateral spines or tubercles ; abdomen well rounded above, flattish beneath. Antennæ filiform, usually 7-jointed in the full-fed nymph. Wing-cases not divergent.

Labial Mask with flat, more or less elongated mentum ; median lobe seldom projecting, often bilobed ; lateral lobes narrow, with apex either pointed, rounded off or truncate, often with a tooth projecting from inner apical angle ; inner border finely crenulate or smooth ; movable hook long, strong, pointed ; position of hinge when at rest very variable, lying sometimes as far forward as the procoxæ, sometimes as far back as the metacoxæ.

Anal Appendages.—The true anal larval appendages consist of a single median *superior appendage* (*appendix dorsalis* of Heymons), which is an outgrowth from the eleventh tergite, and two lateral *inferior appendages* (the true *cerci* of Heymons), outgrowths from the two pieces of the eleventh

sternite. Besides these, there can be distinguished in both sexes two smaller appendages, often called "lateral," lying on either side of the median superior appendage. These are the *cercoids* of Heymons; they are not functional in the larva, but give rise to the two superior appendages of the male imago, or the two anal appendages of the female imago. In describing exuviae, therefore, I prefer to speak of these as the *involucra of the imaginal appendages* mentioned.

Heymons* was of opinion that the so-called "inferior appendage" of the male imago was developed from the base of the appendix dorsalis of the larva—that is, from the eleventh tergite itself. This is very probably correct. But, in all the male larvæ of *Æschninae* examined by me, the involucra of this appendage can be very clearly seen situated dorsally above the base of the appendix dorsalis (see figures of Plate 7); and by comparison with the same structure in the female nymphs, I have come to the conclusion that this involucre is truly an appendage or outgrowth of the eleventh tergite, and not the tergite or base itself. If I am right in this view, it will add weight to Handlirsch's† argument that the "cercoids" are the true "cerci" regenerated; for this dorsal involucre may then be considered as a regeneration of the "appendix dorsalis." The fact that the original and the regenerated appendages exist side by side in the native nymph is not an objection to this view; because, there being no resting or pupal stage, no other method of "regeneration" is available. In this paper, I shall speak of this dorsal outgrowth above the larval superior appendage as the *involucre of the inferior appendage* of the male imago, since it gives rise to that organ in the male.

The three "*laminae anales*" forming the "telson" are not mentioned in this paper, since they cannot be seen in the *Æschninae* except by removing or opening out the larval appendages.

By referring to Plate 7. figs. 1 and 21, the six appendages of the male nymph can be easily localized; *s* is the superior, *i* the inferior larval appendage, while *ms*, *mi* indicate the involucra of the male imaginal superior and inferior appendages respectively.

Genitalia.—In full-fed nymphs, the males may be distinguished by a very slight median tuberculation ventrally on the second and ninth segments. That of the second indicates the beginning of the formation of the genital fossa and its accompanying parts, and may be called the *involucre of the accessory genitalia*; that of the ninth is the *rudiment of the gonapophyses*. These involucra are too small to possess any taxonomic value, and will not be referred to in this paper. The female nymphs have no tubercle on the second sternite, but a much larger swelling arising from the base of the ninth is very distinctive and of great specific value. This is the involucre covering

* Ann. Hofmus. Wien, xix. (1904) p. 21.

† *Ibid.* p. 59.

the growing parts of the female *ovipositor*, and may be so large as to extend right across the ninth segment and even on to the tenth. In descriptions of exuviae, it will simply be called the *ovipositor* for brevity. For brevity also, I have adopted the plan of describing male and female larvæ or exuviae together, ending with separate descriptions of those sexual outgrowths in which they differ.

In the study of the imagines, I have not included a detailed account of the genital fossæ of the males, reserving these, together with some larval structures (the gizzard and rectal tracheoles), for future treatment. All the Australian forms are easily separated without recourse to this line of study, which is, however, of great importance in groups—such as the majority of the *Libellulinae* and the Holarctic species of the genus *Æschna*—in which the anal appendages of the male are not so clearly differentiated in the various species. It may be mentioned, however, that the Australian members of the second tribe, *Brachytrini*, nearly all possess the structures of the second sternite in very similar form to that already described for *Boyeria* by Walker, with the spines of the anterior lamina not so well developed as in the *Æschnini*. The reduction of the ovipositor in *Notoæschna* has run parallel with a corresponding alteration in the details of the genital fossa of the male, which I have therefore thought it advisable to figure (Pl. 9. fig. 15). Good drawings of the various parts that are sunk deep into the fossa can only be obtained by cutting away the margins of the second tergite; and, owing to their brittleness, the investigation of the parts in detail is best made by preparations from freshly killed specimens. This I have not yet been able to undertake. I have, however, figured and described the fossa of *Austropetalia patricia*, which is of somewhat more general interest.

A list of the material studied is given in an appendix (Appendix A). Mr. Herbert Campion's description of a new subspecies of *Telephlebia godeffroyi*, Selys, is attached, by his kind permission, as Appendix B, and completes the study of this interesting genus. I have also given two comparative tables for reference; the first, inserted before the description of new species of *Austroæschna* (p. 48), gives the main points of difference between the twelve known species of that genus; the second (p. 75) shows the chief differences in the known larvæ of Australian *Æschninae*, and gives the main results of the detailed larval studies at a glance.

Phylogeny and Geographical Distribution.

Walker's latest scheme for the classification of the *Æschninae*, based on those of Karsch and Needham, but with certain amendments, is an excellent one from a phylogenetic standpoint. With his view of *Anax* and *Hemianax* as a direct cœnogenetic offshoot from an archaic *Æschna*-form I strongly agree; for my studies of the larvæ of *Anax* and *Æschna* only tend, in my

opinion, to intensify the exceedingly close relationship between these two genera as compared with others. Conversely, therefore, I am quite unable to subscribe to Cockerell's latest proposition* of setting up the *Anacini* as a distinct tribe co-ordinate in value with the *Æschnini*. No doubt the venation of *Anax* is peculiar, and shows some striking differences from that of other *Æschnines*; but this change is, in my view, of very recent date, and in no way comparable to the two diverging tendencies that have been operating for ages on the two diverging groups—the *Æschnini* and the *Brachytrini*. We have in *Anaciæschna* the connecting-link between *Æschna* and *Anax*, just as we have in *Procordulia* the connecting-link between *Somatochlora* and *Hemicordulia*. Nobody would propose to erect a tribe *Hemicordulini*; yet to me the development of *Anax* from *Æschna* offers an exact parallel to that of *Hemicordulia* from *Somatochlora*, except that the former has been more vigorously cænogenetic, and so shows a greater degree of differentiation. The same causes, also, have operated in both cases—viz. the invasion, by an offshoot of a temperate group, of the warmer tropical or subtropical region, and the attempt to accommodate itself, both in habits of breeding (in still water) and in manner of flight, to the domain of the *Libellulinae*.

On the other hand, when one considers the *Æschnini* inter se, it becomes evident that *Anax* has so far outrun its nearest relatives in cænogenetic development that some recognition of the differences between them is necessary. It seems, therefore, to me advisable to retain the *three* separate series in this tribe, as suggested by Walker—viz., the *Æschna* series, the *Anax* series (including only the genus *Anax*, into which I propose to merge *Hemianax* for reasons given below), and the *Gynacantha* series. This division is strongly supported by the study of the larvæ, so far as I have been able to carry it out. The development of the rectal papillæ in *Anax*-nymphs is very remarkable; and even though it be the direct outcome of the invasion of still water by this genus (the papillæ giving an undoubtedly superior respiration-activity to these larvæ), yet the fact ought not to be overlooked in classification. In the case of *Gynacantha*, I have made what to me seems a most unexpected and extraordinary discovery, that the nymph of *G. rosenbergi* possesses a *splendid set of strong setæ on the lateral lobes of its labium*. If this be a characteristic of the larvæ of the group, it will indeed mark them out as very distinct from all other *Æschnid* larvæ. Again, I can only regard this as another cænogenetic character assumed directly as the outcome of the invasion of still water by these nymphs, directly comparable but in no way related to the similar development in the labium of *Libellulidæ* and of those *Agriionidæ* that breed in still water. It would be most interesting to see whether the rectal gills of *Gynacantha* have developed papillæ

* Proc. U.S. Nat. Mus. vol. xlv. (1913) pp. 577-583.

like those of *Anax*, or whether they show a tendency to form the overlapping tile-like folds of Libellulidæ. Unfortunately, the living larvæ are most difficult to obtain.

Hortense Butler * has proved the existence of two setæ on the lateral lobe of the labium in very young *Anax* nymphs, but these very soon disappear. This might be regarded as proof that the nymphs of *Æschinæ* originally possessed setæ, which later on disappeared, being only retained in *Gynacantha* and as a disappearing remnant in *Anax*. I prefer, however, to see in the phenomenon shown by the young *Anax* nymph an attempt to develop setæ cænogenetically. They may be of use to the very young larvæ, and still may not yet have reached their full cænogenetic development. This view would demand the recognition of the *Gynacantha* larva as the most cænogenetic of *Æschnine* larvæ, with the larva of *Anax* intermediate in position between it and the larva of *Æschna*. Neither the archaic *Petaliini*, nor any of the *Gomphine*, so far as I know, have setæ in the nymphal labium—a strong point in favour of the cænogenetic development of these structures in *Gynacantha*.

To the *Æschinæ* as usually constituted, I also add, as an archaic remnant of undoubted *Æschnine* origin, the isolated *Petalia*-group of genera. These might well be claimed as of co-ordinate rank to the whole of the rest of the *Æschinæ*. I have, however, considered it sufficient to allot to them the rank of a "tribe" within the subfamily, so that we now have three very distinctly marked tribes, which may be named after their most prominent genera, and defined as follows :—

Tribe I. *PETALIINI*.

M_2 distinctly arched upwards near the beginning of the pterostigma, but not approaching M_1 as closely as in other *Æschinæ*. Triangles rather short, usually only two-celled. *Rs* unforked. *Rspl* present. *Mspl* absent. Oblique vein far distal from subnodus. Wings with a set of remarkable semitransparent brown or ruby-red spots along costal border. Eyes touching only for a short distance. Inferior anal appendage of male trifold. Ovipositor of female of typical *Æschnine* form.

Larva with broad flattened abdomen carrying fin-like lateral segmental projections (strongly suggestive of Trilobite ancestry). Dorsal tubercles present. Labium with typically *Æschnine* mentum and lateral lobes; outer apical angle narrow, rounded; inner border finely crenulate. Appendages short, segment 10 small and half enclosed in a hollow of 9.

Includes the genera *Petalia*, *Hypopetalia*, *Phyllopetalia*, and *Austropetalia*, n. g.

* "The Labium of the Odonata," Trans. Amer. Ent. Soc. xxx. (1904) pp 111-134

Tribe II. *BRACHYTRINI*.

Rs symmetrically forked, or unforked. *Rspl* straight and lying only one or two cells' width below *Rs*. *Mspl* similarly developed with respect to *M*₄. Oblique vein very close to subnodus. Eyes touching for a long distance. Inferior anal appendage of male simple.

Larva with elongate abdomen, rounded above, flattish beneath. Head and eyes of moderate size only. Labium with apex of lateral lobe either rounded, pointed, or slightly nodding, but *not* squarely truncated. Superior appendage either very short, or long and sharply pointed.

This tribe includes two series :—

A. *Boyeria* Series, with *Rs* unforked; genera *Allopetalia*, *Gomphæschna*, *Jagoria*, *Linæschna*, *Boyeria*.

B. *Brachytron* Series, with *Rs* symmetrically forked; genera *Telephlebia*, *Austrophlebia*, n. g., *Dendroæschna*, n. g., *Austroæschna*, *Notoæschna*, n. g., *Calieschna*, *Periæschna*, *Nasiæschna*, *Epiæschna*, *Æschnophlebia*, and *Brachytron*.

Tribe III. *ÆSCHNINI*.

Rs unsymmetrically forked, or unforked. *Rspl* much curved concavely to *Rs* and separated from it by three or more cell-rows. *Mspl* similarly developed with respect to *M*₄. Oblique vein very close to subnodus. Eyes and inferior appendage of male as in II.

Larva shaped as in II., but with proportionately larger head and eyes. Labium with apex of lateral lobe nearly always more or less truncated (a few exceptions, viz. *Staurophlebia*, *Æschna constricta*, *Æ. clepsydra*). Superior appendage always long and *bifid at tip*.

Considered zoo-geographically, the *Æschninae* of Australia fall into three very distinct groups, corresponding exactly with the classification given above. These can be defined as follows :—

I. PALÆOGENIC Group. An archaic remnant of a once abundant and widely-spread group, whose origin and course of development are too remote to be determined with any certainty, but whose present characteristics were most certainly not developed within Australia. ‡

Tribe *PETALIINI*.

II. ENTOGENIC Group. A group which has developed its present-day characteristics *within* Australia, and so forms the autochthonous *Æschnine* fauna of the continent *. Tribe *BRACHYTRINI*.

* This statement does not, of course, imply that non-Australian genera of this group originated in Australia. This group is of polyphyletic origin, and contains the remnants of many lines.

Five genera are represented, all belonging to the *Brachytron* Series. These may, however, be subdivided into two well-marked series, as follows:—

- A. *Aphantochrome* * Series, in which a scheme of protective colouring is developed on the wings and body, agreeing with a marked crepuscular and shade-loving habit of flight. This colour-scheme consists of a reduction of the body-coloration to a nearly uniform dark brown, with obliteration of all spots on the abdomen; on the wings, longitudinal brown bands are usually developed. This colour-scheme gives almost complete invisibility to the insect, both in flight and at rest.
Genera : *Austrophlebia*, *Telephlebia*.

- B. *Hylochrome* † Series, in which a scheme of pale markings on a dark ground is developed, agreeing with the forest-haunting habits of the insects. In flight, this coloration appears dark, but does not confer any degree of invisibility; when the insect is at rest, the colouring is completely protective.

Genera : *Dendroæschna*, *Austroæschna*, *Notoæschna*.

III. ECTOGENIC Group. A group which has developed its present-day characteristics *outside* Australia, and is only represented therein by immigrants of comparatively recent date. All three series are represented, each only by a very few forms. Tribe *ÆSCHNINI*.

A. *Æschna* Series. Genus *Æschna*.

B. *Anax* Series. Genus *Anax* (including *Hemianax*).

C. *Gynacantha* Series. Genera : *Gynacantha*, *Austrogynacantha* (probably a recent Australian offshoot of *Gynacantha*), and *Helicæschna*.

This tribe includes three series:—

- A. *Æschna* Series, in which the anal triangle of the male is very elongate and the membranule correspondingly large; the larvæ without lateral setæ on the labium and with no papillæ developed on the rectal gills.

Genera : *Basicæschna*, *Hoplonæschna*, *Amphicæschna*, *Coryphæschna*, *Æschna*, and *Anacicæschna* (the latter connecting A with B).

- B. *Anax* Series, in which the anal border of the male is rounded, the sectors of the arculus arise near its upper end; the full-fed larvæ without lateral setæ, but with papillæ on the rectal gills.

Genus *Anax* (including *Hemianax*).

* Greek *ἄφαντος*=obscure, invisible; *χρῶμα*=colour.

† Greek *ὑλη*=forest.

C. *Gynacantha* Series, in which the anal triangle of the male is usually wide and the membranule correspondingly small, the anal appendages of both sexes very long, and the females with a remarkable projecting fork under segment 9; the full-fed larvæ, so far as known, have lateral setæ on the labium.

Genera: *Helieschna*, *Platacantha*, *Cornacantha*, *Triacanthagyna*, *Tetracanthagyna*, *Gynacantha*, and *Austrogynacantha*.

To this tribe also belong the genera *Subæschna*, *Neuræschna*, and *Staurophlebia*, but their correct position within it seems to me too problematical for definite decision until more is known about them.

List of the Known Species of Australian Æschninæ.

I. PALÆOGENIC Group. Tribe *PETALIINI*.

Genus 1. *AUSTROPETALIA*, n. g. (Type *Phyllopetalia patricia*, Tillyard.)

1. *Austropetalia patricia*, Tillyard.

II. ENTOGENIC Group. Tribe *BRACHYTRINI*.

A. *APHANTOCHROME* Series.

Genus 1. *AUSTROPHLEBIA*, n. g. (Type *Planæschna costalis*, Tillyard.)

2. *Austrophlebia costalis*, Tillyard (♂ hitherto unknown, [described herein].)

Genus 2. *TELEPHLEBIA*, Selys.

3 a. *Telephlebia godeffroyi godeffroyi*, Selys.

3 b. *Telephlebia godeffroyi brevicauda*, n. subsp.

3 c. *Telephlebia godeffroyi cyclops*, n. subsp.

3 d. *Telephlebia godeffroyi tillyardi*, n. subsp., Campion.

4. *Telephlebia asthenes*, n. sp.

B. *HYLOCHROME* Series.

Genus 1. *DENDROÆSCHNA*, n. g. (Type *Caliaeschna conspersa*, Tillyard.)

5. *Dendroæschna conspersa*, Tillyard.

Genus 2. *AUSTROÆSCHNA*, Selys.

6. *Austroæschna tripunctata*, Martin.

7. *Austroæschna weiskei*, Förster.

8. *Austroæschna forcipata*, Tillyard (= *severini*, Förster).

9. *Austroæschna unicornis*, Selys.

10. *Austroæschna inermis*, Martin (♀ hitherto unknown,

11. *Austroæschna longissima*, Martin. [described herein].)

Genus 2. *AUSTROÆSCHNA* (*continued*).

- 12 a. *Austroæschna parvistigma parvistigma*, Selys.
- 12 b. *Austroæschna parvistigma flavomaculata*, n. subsp.
- 13. *Austroæschna multipunctata*, Martin.
- 14. *Austroæschna atrata*, Martin.
- 15. *Austroæschna anacantha*, Tillyard (= *aspersa*, Martin).
- 16. *Austroæschna victoria*, Martin.
- 17. *Austroæschna tasmanica*, n. sp.

III. ECTOGENIC Group. Tribe *ÆSCHNINI*.A. *ÆSCHNA* Series.Genus 1. *ÆSCHNA*, Fabr.

- 18. *Æschna brevistyla*, Ramb.

B. *ANAX* Series.Genus 1. *ANAX*, Leach.

- 19. *Anax guttatus*, Burm.
- 20. *Anax gibbosulus*, Ramb.
- 21. *Anax papuensis*, Burm.

C. *GYNACANTHA* Series.Genus 1. *GYNACANTHA*, Ramb.

- 22. *Gynacantha rosenbergi*, Brauer.
- 23. *Gynacantha moesaryi*, Förster.
- 24. *Gynacantha dohrni*, Krüger.

Genus 2. *AUSTROGYNACANTHA*, Tillyard.

- 25. *Austrogynacantha heterogena*, Tillyard.

Genus 3. *HELIÆSCHNA*, Selys.

- 26. *Helieschna simplicia*, Karsch.

I. PALÆOGENIC GROUP.

Tribe *PETALIINI*.*AUSTROPETALIA*, n. g.

Triangles very close to wing-base short, two-celled, followed by two post-trigonal sets of cells in all four wings; basal side very close up to level of areculus. Subtriangles free, preceded by one cross-vein in submedian space. One cross-vein in hypertrigonal space. M_2 undulated. *Oblique vein* far

distal from subnodus. Membranule small, narrow. Pterostigma narrow, fairly long. On all four wings six conspicuous costal spots, transparent ruby-red in colour, edged with blackish, as follows:—a basal spot or streak, extending to first antenodal, in costal space; a small spot on *Sc* halfway to nodus; a larger nodal spot; a medium-sized spot on *R*₁ halfway between nodus and pterostigma; a spot below basal half of pterostigma; and an apical spot or patch. Besides these, in fore-wings of ♀, and often also in ♂, there is a small spot, often nearly a point, on *Sc* between the nodal spot and the one preceding it. Spots of ♀ much larger than those of ♂, and sometimes more or less confluent. Anal border of ♂ excavated.

Eyes touching for a short space. Front broad and high; labium broad. Thorax with three pairs of straight bands, one pair dorsal, two lateral. Legs of medium size, tibiæ with two rows of cilia, but the inner row on protibiæ more numerous and more closely set than the others. Abdomen cylindrical, long and slender in ♂, shorter and stouter in ♀. Auricles very large in ♂, fairly large in ♀. Genital fossa of ♂ widely open anteriorly, narrowed posteriorly by the overlapping margins of the second tergite, which project into two conspicuous pointed prominences; penis ending in two very long thin curved filaments. No conspicuous dilatations of tergal margins underneath 7 or 8. Superior appendages of ♂ short, inferior much longer, trifid.

Type: *Phyllopetalia patricia*, Tillyard.

Habitat. Blue Mountains, N.S.W.

This genus is very closely related to the *Petalia*-group of genera which inhabits Chili, viz.:—*Petalia*, *Phyllopetalia*, and *Hypopetalia*. The following points of difference should be noted:—

1. *Austropetalia* differs from *Petalia* by (a) the greater number of spots on the wings (six instead of four), (b) the form of the pterostigma, and (c) the ciliation of the protibiæ.

2. From *Phyllopetalia* it differs by (a) possessing six wing-spots instead of five, (b) its larger membranule, (c) the different form of the tergal margins in 7 and 8.

3. From *Hypopetalia* it differs by the possession of (a) two-celled triangles (three-celled in *Hypopetalia*), (b) free subtriangles (three-celled in *Hypopetalia*), and (c) the larger membranule.

From all three genera *Austropetalia* differs by (a) the ruby-red coloration of its wing-spots, (b) its broader labium, (c) the form of the appendages of the ♂, the superior being straighter and the inferior longer by comparison than those of the Chilian genera. These differences, coupled with the very distinct habitat, justify the proposition of this new genus. It was, however, impossible to propose it in my former paper, since the male had not then been discovered. I now add a description of the type-male of the only known species.

AUSTROPETALIA PATRICIA, Tillyard. (Fig. 4; and Plate 4. fig. 1.)

Petalia apollo (♀), Tillyard, Proc. Linn. Soc. N.S.W. xxxi. 1906, p. 722.

Phyllopetalia patricia (♀), Tillyard, ibid. xxxiv. 1909, p. 698; plate 55. figs. of larval exuviae, labium, and ♀ imago.

♂. *Total length* 64, *abdomen* 50, *fore-wing* 36, *hind-wing* 34 mm.

Wings (Pl. 4. fig. 1) much narrower than in ♀, the ruby wing-spots much smaller; basal spot forming a mark about 3 mm. long in subcostal space, reaching just beyond first antenodal; mid-spot between base and nodus small and round; about 4 mm. distally from this a tiny round subcostal spot (absent in two other males) on fore-wings only; nodal spot lying distally from nodus, which it borders, nearly 2 mm. squarish; spot between nodus and pterostigma 1 mm., suboval, bordering the radius beneath; spot beneath pterostigma 1.5 mm., lying below proximal half; end-spot 2.5 mm., flat, irregular. *Nodal Indicator* $\left\| \begin{smallmatrix} 13-14, 10-11 \\ 9-10, 9-10 \end{smallmatrix} \right\|$. *Pterostigma*, fore 2.8, hind 3.4 mm., narrow, dark semi-transparent ruby-red between black nervules. *Anal triangle* three-celled, *anal angle* very prominent.

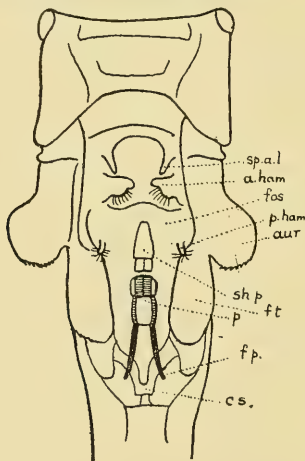


FIG. 4.—Ventral view of second segment of *Austropetalia patricia*; *sp.a.l.*, spines of anterior lamina; *a.ham.*, anterior hamulus; *fos.*, genital fossa; *p.ham.*, posterior hamulus; *aur.*, auricle; *sh.p.*, sheath of penis; *ft.*, tergal fold; *p.*, penis; *f.p.*, filament of penis; *cs.*, carina sterni.

Head.—*Eyes* dark brown; *occiput* black, fringed with dark grey hairs; *vertex* black, small; *front* high, wide, dark brown, with a paler area along the transverse ridge; *clypeus* wide, dark brown with a transverse band of yellow; *labrum* blackish; *labium* dull brown, downy; a yellow rim under eyes.

Thorax.—*Prothorax* small, dark brown. *Meso-* and *metathorax* dark brown, with a pair of narrow dorsal yellowish-green stripes slightly inclined backwards and two rather similar pairs of lateral stripes. *Legs* short, black,

bases of femora brownish beneath; all tibiæ with two rows of short even cilia, the inner row on protibiæ fine and closely set like a comb.

Abdomen.—1-2 swollen, 3 scarcely pinched at all, 4-10 cylindrical, 7-10 only very slightly widened. *Genitalia* of segment 2 with the spines of anterior lamina bluntly pointed, the anterior hamuli not pointed, irregularly rounded and lobed, carrying hairs on posterior border; posterior hamuli small, placed vertically against the tergal folds, tips carrying hairs; auricles large and rounded, with posterior border carrying a set of small spines or teeth; tergal folds prominent, oval in ventral view, with fairly denticulate margins; in lateral view they rise up posteriorly to a fairly sharp prominence; penis with a pair of long curved end-filaments, projecting ventrally far beyond the level of the folds; sheath of penis placed completely in front of penis and scarcely enclosing it at all (fig. 4, also Plate 9. figs. 10, 21). *Colour.*—1, brown; rest dark brown marked with green (yellowish in immature specimens) as follows: 2, a touch of green on each side of dorsum, auricles yellowish green; 2-8 with very distinct transverse central carinæ; 3-7 with a pair of basal dorsal lines reaching to carina, a pair of sublateral spots, and a pair of central spots wider apart, lying just distally from carina; 8 with similar markings, but basal dorsal lines short, and central spots enlarged with a pair of lines covering the apical three-fifths of the segment; 9 with basal lines, a pair of very small basal sublateral spots, and a pair of fine dorsal lines; 10, a pair of thicker dorsal stripes.

Appendages.—*Superior* 1.2 mm., thin, very slightly waved, blackish; *inferior* 2.3 mm., large, trifid; the central tip truncate, projecting far beyond superiors; lateral tips small, rather pointed, and upturned so as nearly to meet tips of superiors; colour semitransparent brown in centre, shading to blackish along edges (Plate 9. figs. 8, 9).

Types: ♂ ♀, Coll. Tillyard (♂ type, Katoomba, Nov. 16th, 1912).

Larval Type *: ♀ unique, Coll. Tillyard.

Habitat. Blue Mountains, N.S.W., from 2000-4000 feet; especially around Katoomba (above 3000 feet), October and November.

There are very few records of captures of this very rare insect. In November, 1903, Mr. G. A. Waterhouse captured two females at Leura (one of these is the type ♀, the other is said to have been sent to Cambridge, England). On Nov. 9th, 1908, Mr. K. Brown discovered a larval skin and newly emerged ♀ imago at the Leura Cascades. They were just about to be washed away by the quickly rising water during a heavy storm. Each year a sharp look-out is kept for it by collectors, but no further captures were made until Oct. 6th, 1912, when Mr. G. J. Waterhouse captured another ♀ in his garden at Woodford (2000 feet). On Nov. 10th, 1912,

* The term "Larval Type" is here used to indicate the actual specimen (be it exuviae or full-fed nymph) from which the description is made. It is, of course, not a "type" in the sense of fixing the species.

Mr. Goldfinch netted two fine males near Katoomba. The day was dull and sultry, and the insects were sitting quietly on twigs. The following week I visited Katoomba, during very hot weather, and saw several specimens flying swiftly along the edge of the precipice at Leura as early as 5.30 A.M., the temperature being already over 80°. About 7 A.M., the temperature then being nearly 90°, the flight was almost over, but I was fortunate enough to capture a fine male flying swiftly along the track to the falls. This is the type ♂. By 10 A.M., the temperature having reached 98°, not an insect was to be seen. The rest of the day was spent in a vain search for more specimens. The next day a southerly change with rain, and a drop to about 40° in the temperature, put an end to all collecting.

This year Mr. Goldfinch and Mr. G. A. Waterhouse took five females at Katoomba on Oct. 6th, and I was fortunate enough to obtain several specimens of both sexes during two visits on Oct. 11th and 18th. From a mature ♀ I extracted a fair number of ova, which I found to be of the typical *Æschnine* form, very elongated, and even more pointed than usual (Plate 9, fig. 24, compare figs. 22, 23). A very careful search for both living larvæ and exuviae has so far proved fruitless.

The flight of this insect is distinctly *Æschnine*, but with some individual peculiarities. Usually it does not fly very fast and is fairly easy to capture, especially because of its fondness for resting on twigs or leaves of bushes. It avoids the more open spaces and prefers to fly in the forest, either round the trees or along narrow tracks. In such places its coloration renders it dark and very difficult to see. When approaching a bush to rest the insect drops suddenly close to the ground and then *rises* to its resting-place. Other *Æschnine* have a similar habit, but not quite so marked; whereas *Gomphine* nearly always approach a twig from above. Sometimes, when disturbed, these insects will circle about in complicated evolutions, often getting up a great speed and finally making off with great rapidity.

The living larva of this species would be of the greatest scientific importance, and is probably, next to the larva of *Chlorogomphus*, the most valuable phylogenetic clue yet to be discovered amongst our existing Odonata. The structure of the rectal gills and of the gizzard should prove of immense interest. Unfortunately, I am so far completely at a loss in my search for it. In the case of *Petalura* it was purely by chance, after four years' searching, that I discovered the secret of its larval history, and probably the solution in the case of *Austropetalia* will not be arrived at any more easily. The form of the ovipositor and the sharply pointed ova prove indisputably that the female oviposits in vegetable tissues; but the build of the larva, with the fin-like lateral lobes of its abdominal segments (almost suggesting a remnant of Trilobite ancestry), is so peculiar as to offer no safe guide as to its habits. I have dredged and examined every hole and corner of two likely creeks at Katoomba, without the slightest success.

There are two points of great interest in connection with the group *Petaliini*, to which this insect belongs. They are (1) the question of its Æschnine affinities, (2) its remarkable geographical distribution. I propose to deal briefly with them here :—

1. The Æschnine Affinities of the *Petaliini*.

I have already dealt with this question in a former paper (*loc. cit.*). Some further strengthening of the evidence in favour of the position maintained in this paper is afforded by the following points :—

(a) On making a further study of the labium of the larval exuviae, I find that I had figured as the suture of the movable hook a crack or bent which occurred below it on one side. By warming the labium in water and spreading it out under a glass slide, I have been enabled to draw it correctly, and offer the amended figure herewith on Plate 5. fig. 12. It will be seen that the structure is almost exactly of the same form as that of *Austroeschna unicornis pulchra*, fig. 3.

(b) The form of the ova is, as expected, distinctly Æschnine, corresponding to the generalized Æschnine ovipositor possessed by the female.

(c) The habits and flight of the species, so far as I have been able to study them, are distinctly Æschnine.

The upward curving of M_2 at the beginning of the pterostigma has been already noted as important evidence in favour of the Æschnine affinities of the group; and also, of course, by the same reasoning, we must regard the *Cordulegaster* type of wing as an independent convergence towards the *Petaliini*. The rounded lobes of the anterior hamuli in the male of *Austropetalia* suggest some resemblance to the corresponding structures in *Cordulegaster*, but the point does not seem to me of great importance. In the larva, the structure of the head, labium, and antennæ are distinctly Æschnine. The form of the abdomen, however, is unparalleled in any group, and suggests some specialized larval habit not adopted by any other group. Possibly it is connected with the fact that the larvæ dwell in small creeks just above exceedingly precipitous cascades and waterfalls, and are able to use their lobate abdomen in some manner to prevent themselves from being swept away.

2. The Geographical Distribution of the *Petaliini*.

From Chili six species have been recorded, referable to three genera. From Australia only one species is known. The group does not occur elsewhere, and has no near allies. The four genera comprised within it are, however, very closely allied, and might even strictly be considered as only of subgeneric rank.

This peculiar distribution may be accounted for in two ways :—

A. The existing forms may be an archaic remnant of a once exceedingly abundant group, which has since died out in all other localities. If this be

so, no special significance can be attached to its present occurrence in two so widely separated localities; for these remain simply as the last refuges of a dying group.

B. They may be the remnants of a group that developed in Antarctica at a time when that region enjoyed a temperate climate, and were, later on, driven out along two separate land-connections—the one leading to the mountains of Chili, the other to those of Eastern Australia. If this be so, the *Petaliini* afford direct evidence of a former land-connection, *viâ* Antarctica, between Australia and South America.

Some light may be thrown upon this question by studying the present distribution of another archaic remnant of the *Æschnidæ*, viz. the *Petalurinae*. Seven species are known, referable to four genera—just exactly the same number of species and genera as in the case of the *Petaliini*. But the forms are not so closely allied to one another, and their distribution is more widely spread. Three species (genus *Petalura*) occur in Eastern Australia; one species (genus *Uropetala*) in New Zealand; one species (genus *Phenes*) in Chili; and two species (genus *Tachopteryx*) in North America.

In a case such as this, supposition A is the only possible explanation. We could scarcely argue that the distribution of the *Petalurinae* really offers any evidence of a land-connection between Australia and the New World. If in course of time the genera *Tachopteryx* and *Uropetala* became extinct, the *Petalurinae* would then offer to us a distribution very similar to that of the *Petaliini* at the present day.

Against this line of argument, and in favour of supposition B, we can only offer very little evidence. The strong point in favour of B seems to me to be the exceedingly close agreement between the Chilian and Australian forms of *Petaliini*. In the case of the *Petalurinae* the typical expanded superior appendages of the male *Petalura* and *Uropetala* (Australian group) are not found in the American genera. There is also a considerable difference in venational and other details. But in the *Petaliini* all forms seem to have preserved not only the wonderful wing-spots, but also the peculiar trifold form of inferior appendage of the male. So striking are these characters, and so closely similar is the Australian species to its Chilian relatives, that one is much tempted to explain them as two separate lines of development from a single Antarctic genus, which was driven out from that region along two distinct land-connections, and has since diverged but slightly from its original form.

There is now incontrovertible evidence that the climate of Antarctica was once temperate, but we cannot yet be certain how late it remained so. Fossil Odonata of the Jurassic and succeeding periods are fairly rich in forms not far removed from the *Petaliini* (e. g., *Cymatophlebia*), so that it is quite possible that the *Petaliini* themselves became established about Cretaceous times. This would give plenty of time for the required segregation of the

group in Antarctica (due to pressure of competition with newer forms) and for a subsequent exodus along land-connections to Australia and Chili when the Glacial Period intervened.

This theory would undoubtedly be strengthened by the discovery of a Tasmanian species. A form that finds the climate of the Blue Mountains suitable should surely also be able to find suitable refuges in Tasmania, *if it came that way*. No such species is known at present; but, owing to the small amount of collecting of Odonata carried out there, and also to the extreme difficulty of finding these insects (witness the slow accumulation of records for *A. patricia* in a locality within easy reach of Sydney), we cannot be sure that one does not exist. Meanwhile, we must regard the evidence for supposition B as insufficient, however tempting and fascinating the hypothesis itself may appear.

II. ENTOGENIC GROUP.

Tribe *BRACHYTRINI*.

A. APHANTOCHROME SERIES.

Coloration dark brown, with more or less complete suppression of all spots and bands; wings nearly always marked with dark brown costal or subcostal bands. This colour-scheme gives almost complete invisibility to these insects when at rest. Flight rapid and ghost-like, the colour-scheme giving semi-invisibility. Habits more or less crepuscular.

Genera :—

- | | |
|--|------------------------------|
| 1. Basilar space free, subcosta normal at nodus | <i>AUSTROPHLEBIA</i> , n. g. |
| 2. Basilar space reticulated, subcosta prolonged through nodus
for one or two cells' distance | <i>TELEPHLEBIA</i> , Selys. |

Genus 1. *AUSTROPHLEBIA*, n. g.

Neuration very close, with numerous ante- and postnodal cross-veins closely set. *Rs* strongly forked about midway between nodus and pterostigma; *Rspl* placed one row of cells below inferior branch of fork. *M*₂ much arched above the superior branch of fork of *Rs*. Sectors of arculus just fused at bases. Pterostigma well braced. Triangles elongate, six- to nine-celled (Plate 8. fig. 6); distal side distinctly bent at join of trigonal supplement (*Ts*). *Mspl* long, nearly straight, lying one row of cells below *M*₄ and one row above the continuation of *Ts*, to which therefore it is not joined. *Sc* normal at nodus; basilar space free; submedian space with five or six cross-veins; subtriangles with one cross-vein; hypertrigonal space with seven to ten cross-veins. Anal loop compact, of three to four cells' width. Membranule fairly large, but not reaching downwards along the

border of the wing to any extent. Anal triangle of male right-angled, strong, three- to four-celled, ending some distance above anal angle; the latter strong, right-angled.

Front prominent, anvil-shaped. Abdomen of male with prominent auricles, and strongly constricted at segment 3; that of female cylindrical, segment 9 carrying a strong projecting ventral shelf armed with a saw-like set of teeth (Plate 8. figs. 3-4).

Type: *Planæschna costalis*, Tillyard.

This genus is closely allied both to *Telephlebia* and to *Austroeschna*. From *Telephlebia* it differs as indicated above, also by the fused bases of the sectors of arculus, and by its great size; from *Austroeschna* by its anvil-shaped front, great size, dense reticulation, much longer and more reticulate triangles, and by its peculiar colour-scheme.

AUSTROPHLEBIA COSTALIS, Tillyard. (Plate 2. figs. 1-3; Plate 4. fig. 2).

Planæschna costalis, Tillyard, Proc. Linn. Soc. N.S.W. xxxi. (1906) p. 724.

Austroeschna costalis, Martin, Æschnines, Coll. Selys, fasc. xix. (1909) p. 101.

Telephlebia racleayi, Martin, ibid. p. 142.

Telephlebia macleayi, Martin, Genera Insectorum, fasc. 115 (1911) p. 22.

The descriptions cited above all refer to the type female, for many years the only known specimen of this rare insect. It is in the Australian Museum, Sydney; its locality is given as "N.S.W.," date "about 1870," and it was originally labelled "*Petalura costalis*" in some unknown handwriting. The re-discovery of this fine insect and the successful search for its larva are of sufficient interest to be given in detail, followed by a full description of both larva and imago.

Ever since the discovery of the type female (hidden away in a box in the Australian Museum, where it had attracted no attention), I had kept a sharp look-out for this species in all my collecting-expeditions; but without success for nearly six years. In 1911, owing to ill-health, I was obliged to leave Sydney with my wife and family in October, and visited the rich scrubs of the Dorrigo Tableland, situated some three hundred miles north of Sydney. Owing to the dry weather and heat, collecting was very disappointing, very few Odonata being seen during the first three weeks. On November 16th, about 5 P.M., after a very hot and trying day, my wife and I took a short walk into the dense scrub close to the house at which we were staying. This scrub, lying just on the south side of the town of Dorrigo, is known as the "Rifle Range," and is exceedingly picturesque; a long "riding" had been originally cleared in it for rifle-practice, but this was now overgrown again, and only the tracks of the woodcutters were left. Entering by a narrow

pathway, we were soon in the twilight of the scrub. Huge trees towered overhead, a dense mass of fern covered the ground, while every few yards splendid tree-ferns (*Dicksonia* and *Alsophila*) raised their graceful forms. Here and there were small dense thickets of native raspberry (*Rubus parvifolius*), fringed round by small prickly bushes, the whole being matted into an impenetrable tangle by the hanging festoons of lawyer-vine (*Calamus Muelleri*) and other climbers. In such a place as this the path passed some hundred yards or more above the beginning of a small gully, down which the soakage from the surrounding scrub trickles as a tiny streamlet. Quite suddenly there flew out from the underside of a tree-fern a magnificent Dragonfly, which dashed forward in front of us, and settled on the tangled mass of prickly lawyer-vine fringing the thicket already described. I had no net with me, but we crept cautiously forward in the dim light until we stood within 10 feet of this lovely creature, which hung motionless and vertically on the vine, its rich brown wings outspread, and appearing almost part of the dense mass of dark twigs and stems around it. I recognized it at once as a fine newly-emerged female of *A. costalis*; the problem was, how to catch it. Leaving my wife as sentinel, I rushed back for my net, returning breathless a quarter of an hour later to find no change in the position. Knowing the hopelessness of dealing with lawyer-vine, there was only one thing to do—to strike broadside on and trust to the Dragonfly darting out into the net. I struck, but the Dragonfly was too quick, and escaped by a few inches, leaving the net hopelessly entangled and of no further use. As we had not seen the insect career away, we began to search for it around us. It had dodged behind us, and, turning round, had “hung up” on some low creepers only 2 feet from the ground, almost in darkness. Here I found it and extending my hand slowly, without any jerking movement, seized it by the abdomen.

The next day I visited the same place at the same time, and flushed another fine newly-emerged female within a few yards of the same spot. This time I made no mistake, but secured it at the first stroke from off the trunk of a tree-fern.

I then set about finding the male and the larva. The “Rifle Range” was about a square mile in area, situated mainly on a fairly steep hill-slope, and intersected by small gullies down which ran small mountain-creeks. The first week I spent working round the immediate locality of my captures, and dredging the pools of the small creek just below, without success. Ranging further afield, I discovered and explored from end to end five separate small creeks, all difficult of access and lying in steep rocky beds. These all join at the lower end of the scrub into one strongly running stream. Each was worked from top to bottom with the dredge-net, and ferns and creepers were continually shaken in the hope of dislodging another specimen. Finally, on Dec. 8th, I reached the farthest boundary of the scrub, and found

close to it the largest of the five small creeks. This was bordered with splendid tree-ferns, and here and there opened out into fairly deep pools, full of the decaying trash of sticks and fern-leaves. Striking up the rocky bed of this creek, I reached at last a small and narrow gorge, whose sides rose 50 feet and were a dense mass of prickly bushes and creepers. A few yards above this a beautiful little waterfall tumbled down from an overhanging ledge. All around was a dense mass of fern growing on vertical rocks *. As I looked up at this scene, a fine male of *A. costalis* darted out from under a tree-fern and settled in the prickly mass of bushes 30 feet above me. Marking the spot, I clambered up through the steep thicket as best I could, dragging my net flat on the rocks behind me, until I was able to sit down within striking distance of my quarry. He was perched, as luck would have it, in about the only place where a stroke of the net was possible. This was done by pushing the net very slowly along the ground until it was under him, and then striking quickly upwards, thus securing the Dragonfly together with the broken twig on which it was resting.

The next day I searched again for the larval skin by wading up the same creek, and examining every single frond or twig that either drooped into or stood up out of the water. After three hours' work, during which time I had covered nearly three-fourths of a mile of creek and had examined some hundreds of leaves and sticks, I arrived within two hundred yards of the waterfall. Here, on lifting up a large drooping frond of tree-fern from the water, my hand touched a perfect larval skin, which, clinging close to the brown midrib of the dead frond, was almost indistinguishable from it in coloration. It was the skin of a male, most probably of the male which I had captured the day before, for I never found another.

The same year (1911) two of my entomological friends, Mr. A. H. Lea and Mr. H. J. Carter, coleopterists, visited Mount Tambourine in South Queensland. They returned with a report of an enormous brown Dragonfly, seen on one of the small mountain-creeks there, which they had failed to capture owing to its great speed. I determined to visit this new locality, which I reached just before Christmas, 1912. The weather was continuously wet, but Odonata were abundant. In a day or two I was rewarded with the sight of a fine *A. costalis*, which passed me at lightning speed late one afternoon, as I was exploring a small creek. The next day, on visiting the same spot about 5 P.M., another male appeared, and flashed by me before I could even think about striking. Realizing how impossible it was to hope to catch them without strategy, I carefully examined the creek, and finally selected a very narrow opening between two reed-clumps, where it seemed to me the Dragonflies might either pause in their flight or be struck at while passing swiftly through the narrow passage. (This place is seen in the foreground

On these ferns I took on the same day a new species of *Agriolestes* (*A. fontanus*).

in Plate 1. fig. 2.) Arriving here about 4.30 P.M. each day, I waited patiently for the arrival of my Dragonfly. Facing up the stream, I commanded an uninterrupted view of between fifty and a hundred yards of the creek-bed, which was very narrow, shallow, and closed in by palms, ferns, and trees. At the top end was a low ledge of rocks and a small pool. Over this ledge of rocks the Dragonfly would drop swiftly in ghost-like fashion, its remarkable coloration making it almost invisible except as a diffused and rapidly moving blurr. Again and again I saw the insect appear thus far ahead of me, only to realize that it had passed me before I could strike. Its speed must have been quite equal to that of a *Macronia*, generally admitted to be the swiftest of all Dragonflies. In a day or two I got more used to the habits of the species, and at last captured a fine male as it careered past me. The next day I repeated the performance, and at the end of three weeks I had six fine males to my credit. Females were obtained by beating clumps of tree-ferns towards evening, when they would fly wildly out and occasionally return after careering about for a few minutes : of them I captured four altogether.

A half-grown larva was taken alive under one of the flat rocks in the bed of the small creek shown in Plate 1. fig. 2, while a male larval skin was taken on some native arums at the back of the large pool shown in Plate 1. fig. 1. In the afternoons, when parties of visitors were bathing in this pool, *A. costalis* used to appear suddenly and career with lightning speed around. It was here that I once saw a pair *in cop.*, and noticed that the male occasionally accompanies the female while ovipositing. But it is more usual for the female to oviposit by herself. This is done towards evening, or, in dull days and in deep secluded parts of the creeks, perhaps earlier. The female flies more slowly than the male, examining carefully all the ins and outs of every little pool, and pausing at every fancied spot. Every now and then she would half-settle with quivering wings on some small log or stick, and, inserting her abdomen into the water, place one or two eggs into the submerged tissue of the wood. This was done by a quick to-and-fro movement first of all, which I have no doubt was a sawing or rasping of the wood by the projecting teeth of segment 10 ; then the abdomen would be curled up somewhat, and pressed downwards two or three times into the water. This latter movement was clearly the actual placing of the eggs in the newly-opened wood-tissues.

A few notes which I made concerning the remarkable flight of this insect may be of interest. First, as to its speed. It is notoriously difficult to judge the speed of a small object, but I made one or two attempts to do so. The distance from my watching-place, in the foreground of Plate 1. fig. 2, to the ledge of rock over which the swift-flying males first appeared was, as near as I could judge, about eighty yards. From the time they first appeared to the time they passed me was barely sufficient for me to grip my net and

steady myself to strike. At the most it could only have been two or three seconds, which gives these insects the almost incredible speed of about sixty miles an hour. Owing to the excitement of watching their on-coming, and the impossibility of calmly counting off accurate seconds in one's mind, I cannot give an exact time, but I do not think that I have erred far in stating their speed.

As regards the manner of flight, the males keep very close to the water—not more than a foot above it. Coming straight towards the observer, the body, as well as the wings of the insect, is almost invisible, being dark brown against a very similar background. The insect approaches as a rapidly pulsating shadow, each pulsation being a very small vertical rise and fall, occupying perhaps a fifth of a second, and representing one dart or jerk forward of the wings. Standing away from the creek and observing the insect sideways, the body is slightly more visible, and the jerks can be plainly seen, each bearing the insect forward for a considerable distance. These jerks are only made when the insect is being impelled forward straight. In rounding the edge of a pool, the wings are held in a plane slightly inclined from the horizontal towards the momentary centre of curvature of the path, and the jerks recommence, often with a sharp crack, as soon as the horizontal position is again assumed. No effort at all was apparent in passing over vertical obstructions, such as low rocks in the bed of the creek. Poising or hovering, however, is not so easy to these insects as to some of the smaller *Æschninæ*. I seldom saw a male stationary; but when they do poise, there is a distinct effort both to stop and to start, not infrequently accompanied by a sharp crack or a whirring noise from the rapidity of wing-movement.

The earliest time of day at which I saw this insect in flight (apart from occasionally disturbing resting females in the morning) was about 1 o'clock on a dull stormy day. They seldom fly at all until 4 P.M., but from that hour to sunset they are particularly active. At all times they avoid the open or sunny parts of the creeks, and keep to the deeply shadowed portions, along which their remarkable colour-scheme serves to render them so little visible.

I had several opportunities of observing the efficiency of this colour-scheme when the insect is at rest. The favourite resting-place of the species, and especially of the females, is the underside of a large tree-fern frond. The colour of the midrib is exactly that of the Dragonfly's body, and the four brown bands along the extended wings give them just exactly the appearance of four brown twigs. Once I disturbed a female which flew up on to the underside of a tree-fern frond only a few feet from me; but I was quite unable, in the poor light, to make out the exact spot; though as soon as I touched the frond the insect darted out quite close to me. Other favourite resting-places of the females are on the underside of large fallen logs spanning the creeks, and also fairly high up on the smaller branches of trees, where they are almost invisible.

Two other records of this fine insect have been made since my captures at Tambourine—viz., a single male taken at the head of the Condamine River, near Killarney, Queensland, by Mr. E. J. Dumigan, Jan. 1913; and a fine male taken by Mr. Goldfinch at Stanwell Park, N.S.W., in Feb. 1913. Mr. E. P. Dodd took a single female at Herberton, N. Queensland, in Jan. 1911, and Mr. E. Cheel a damaged female at Hill Top in Feb. 1912. The measurements of these different specimens are given in the appended description.

♂. Wings.—*Neuration* brown, costa russet-brown; a conspicuous band of dark russet-brown running along the whole costal length of the wing; from base to nodus this band fills the subcostal space, but only encroaches on the costal space basally and again near the nodus; it also fills the radio-medial space from arculus to nodus; beyond nodus it fills both costal and radial spaces completely to tip of wing. *Pterostigma* 6 mm., rose-pink. *Membranule*: fore small, 1.5 mm., whitish; hind 2.5 mm. long by 1.2 mm. wide, whitish. *Nodal Indicator* $\left\{ \begin{array}{l} 35-36, 34-35 \\ 27-29, 35-36 \end{array} \right\}$.

Head.—*Eyes*, *occipital triangle*, and *vertex* dark brown; *front* russet-brown at base, shading to blackish along the transverse ridge of the anvil-shaped projection; the whole face, including distal part of front, *clypeus*, *genæ*, and *labrum* clear ochreous; *labium* dark brown, *mouth* edged with black.

Thorax.—*Prothorax* inconspicuous, brown. *Meso-* and *metathorax* dark chocolate-brown; dorsal ridge raised into an obtuse-angled semi-transparent spine; a pair of regular cream-coloured humeral bands running from interalar ridge down to just above mesocoxa; a pair of almost parallel and similar lateral bands running from between the wing-bases to base of metacoxa, and continued backwards more darkly and faintly across notum, which is dark brown. Underside with a large inverted V-shaped cream-coloured mark running out enlarged on to sides of segment 1 and part of 2 of abdomen. *Legs* rather short, strong, brown except upper part of prefemora and all tarsi, which are blackish; protibiæ with an outer set of 8-9 stiff cilia, an inner set of 4-5 smaller, followed by an apical comb of short closely-set bristles; other tibiæ with two undifferentiated sets of 8-10 stiff cilia.

Abdomen.—1-2 swollen, 3 much pinched basally, 4-10 slightly widening from 3 mm. across 4 to 4 mm. across apex of 10. *Colour* dark brown, with slight shading to medium brown on 1, base and apex of 3 laterally, apices of 4-6 laterally, and on dorsum of 9-10. 1-2 with creamy sublateral extension of thoracic V-mark; auricles of 2 large, brown; genitalia of 2 bordered on each side by a conspicuous straight narrow band of cream-colour, tergal margins of 2 enormous, partly concealing the genital fossa; spines of anterior lamina rather small, sharp, partly hidden by irregularly placed soft hairs, as are also the somewhat elongated oval anterior hamuli.

10 almost square above, rising dorsally into a conspicuous but rather blunt subapical tubercle.

Appendages.—*Superior* short, forcipate, rather flat, 3·8 mm., brown; inner margin finely serrate and carrying fine hairs. *Inferior* 2·7 mm., subtriangular, much upcurved, hollowed out above and below, shining brown, downy, outer margins hairy; tip blackish, slightly sub-bifurcate (Plate 8. figs. 1, 2).

♀ similar to ♂, but larger, differing as follows:—*Abdomen* 1–2 much enlarged, 3–10 cylindrical; 10 without dorsal tubercle, but with a rounded tubercle projecting under and between appendages; 9 with a paler and more projecting inferior shelf, ending in a rounded cutting-edge or saw of 10–11 teeth (Plate 8. figs. 3, 4). *Ovipositor* pale brown, edges of terebra darker; *styli* two-jointed, widely divergent, basal joint 2 mm., dark brown, apical joint 1 mm., slender, pale brown (Plate 8. fig. 5). *Appendages* 1·5 mm., straight, with rounded tip, brown. *Pterostigma* 6·5 mm., ochreous at first, becoming dark brown in very mature specimens.

The following table shows the variations in size (all lengths in mm.):—

Specimen.	Total length.	Abdomen.	Fore-wing.	Hind-wing.	Expanse.
Type ♂ (Dorrigo)	90	70	63·5	62	132
Type ♀ (N.S.W.)	92	69	69	68·5	144
♂ ♂ (Mt. Tambourine)	87–93	66–73·5	61–62·5	59·5–62	127–131
♂ (Killarney)	87	65	61	60	128
♂ (Stanwell Park)	93·5	73	63	62·5	133
♀ ♀ (Dorrigo)	92	70	70	68	145
♀ ♀ (Mt. Tambourine)	87–93	65–70	66·5–70	65–68·5	137·5–145
♀ (Hill Top)	89	68	68	67	? (damaged)
♀ (Herberton)	86	66	66	64	135

This table shows considerable variation in size. The largest male is that from Stanwell Park (from which locality, therefore, one might expect to get a female larger than any yet discovered); the largest female from Mount Tambourine. The smallest males are from Killarney and one from Mt. Tambourine, the smallest female from Herberton.

The Herberton female is somewhat different from the type-form, the humeral bands of thorax being reduced to creamy lines edged with brown, the lateral bands darker than usual, the whole coloration darker; pterostigma 5·5 mm., dark brown; brown bands of wings paler and much less conspicuous than in type-form. In the Hill Top ♀ the wing-bands are somewhat narrower and less regular than usual.

Types: ♂ (Dorrigo, N.S.W.), Coll. Tillyard. ♀ (N.S.W.), Australian Museum, Sydney, N.S.W.

Habitat. N.S.W. and Queensland; confined to small rapid creeks in mountainous districts with thick scrub or forest. Dorriggo, N.S.W. (1 ♂ and 2 ♀ ♀ taken by myself, Nov.–Dec. 1911); Hill Top, N.S.W. (1 ♀, damaged, taken by Mr. E. Cheel, Feb. 1912); Stanwell Park, N.S.W. (1 ♂ taken by Mr. Goldfinch, Feb. 8th, 1913). Mount Tambourine, Queensland (6 ♂ ♂, 4 ♀ ♀ taken by myself, Dec. 1912); Killarney, Q. (1 ♂ taken by Mr. E. J. Dumigan, Jan. 1913); Herberton, Q. (1 ♀ taken by Mr. F. P. Dodd, Jan. 1911).

Description of Larva (Plate 2. fig. 3).

♂. *Total length* 48 mm., *head* 7 × 9.5 mm.; *thorax*, prothorax 7, meso-metathorax 9 mm. wide; *abdomen* (excluding appendages) 27 mm., widest at segment 7 (9 mm.).

Head.—*Postocular lobes* rounded, 7 mm. from end to end; *vertex* flat; *eyes* 1.2 mm. apart at nearest; very dark brown speckled with pale brown; *front* narrow, 3 × 1 mm., very dark brown above, crossed by a pale brown bar; *clypeus* and *labrum* brown, *genæ* paler brown.

Labium brown, 11 mm. long by 6 mm. wide in position of rest, hinge reaching to well below mesocoxæ (Plate 6. fig. 1). *Mentum* elongate shield-shaped; *median lobe* very slightly cleft medially, and carrying on each side a conspicuous horny tubercle and a fringe of stiff hairs. *Lateral lobes* with very long and slender movable hook; apex truncate, with slightly nodding outer angle; a series of fine crenations along inner margin (Plate 5. fig. 1).

Thorax.—*Prothorax* dark brown, lateral lobes rounded; two sharp spines placed well forward on each side. *Meso-* and *metathorax* dark brown, carrying about the middle of each side a conspicuous obtuse-angled tubercle. *Wing-cases*: fore 11, hind 10.5 mm., reaching just beyond end of segment 3 of abdomen.

Abdomen well rounded above, slightly convex beneath. No dorsal spines; *lateral spines* as follows:—2–3 obtusely angulated medio-laterally, 4 with a very fine spine at lateral angle, 5–9 with very conspicuous spines increasing in size. Segment 10, 2 mm. long by 4 mm. wide, slightly angulated only. *Involucra* of male imaginal appendages:—Dorsal (inferior) 1.5 mm., triangular; lateral (superior) 1.5 mm., sharply pointed. *Appendages*: *superior* 3.8 mm., very sharply pointed, slightly downcurved; *inferior* 4 mm., also very sharply pointed, slightly incurved at tips (Plate 7. figs. 1, 13).

♀. Very similar to ♂, but easily distinguished by the large ovipositor (Plate 9. fig. 1) covering the middle ventral surface of 9 and 10, and projecting considerably beyond end of 10; the strongly upcurved tip resting between the bases of the two inferior appendages; *involucra* of female imaginal appendages sharply pointed.

Larval Types (mounted *exuviae*), Coll. Tillyard.—♂. Dorriggo, N.S.W., Dec. 9th, 1911. ♀. Stanwell Park, N.S.W., Feb. 22nd, 1913.

(Mr. G. A. Waterhouse). There are also in my collection three other male exuviae : one taken at Mt. Tambourine, Queensland, in Dec. 1912 ; the other two from Stanwell Park, Feb. 1913.

Habits.—A single living larva, half-grown, was found by me on the underside of a flat rock lying in the bed of the small creek at Mt. Tambourine. The larva is almost black in colour, with rich brown markings. It can cling very closely to the surface of the rock, and can also run fairly quickly. The lateral spines, which are very sharp, can be used as a means of defence ; for, as the animal wriggles to escape, these spines prick one's hand. But the chief object of the spines is, I think, to prevent the larvæ being washed away during a flood or heavy spate in the creek. It is by means of these spines that the larva is enabled to press so closely to the rock-surface, while resisting the onrush of water, with its head facing upstream. Also, if by any chance the larva is washed from its rocky refuge, it can hide itself in the trash of the deep holes and hollows, where the spiny lateral surface, by catching against obstructions, prevents it being swept away down-stream.

The half-grown larva which I found was placed in water in a large jar, and supplied with sticks to cling to. About 10 P.M. I went to look at it, and found that it had climbed out of the jar and was crawling along the table. I replaced it, but the next morning I found it lying on the floor dead. I concluded from this that these larvæ are in the habit of leaving their rocky retreats in the night-time and wandering about in damp places in search of food. As they usually hide on the under surface of flat rocks, in small cracks and crannies where a supply of food could not possibly be obtained during the daytime, it is not surprising to find that they roam about at night. Further details of similar interesting habits will be found below, taken from my observations of the nymph of *Telephlebia godeffroyi*.

The fact that the larva was only half-grown (it was as large as a full-grown *Austroaeschna*-larva, but the wing-cases were only just appearing) points to the period of larval growth being two years, since the imago emerges in November, and this larva was found in December.

Genus 2. TELEPHLEBIA, *Selys*.

Neuration close or fairly close. *Rs* forked at a point very considerably nearer pterostigma than nodus ; *Rspl* one row below ; *M*₂ arched above fork. Sectors of arculus separate at bases. Pterostigma well braced. Triangles of moderate length, three- to five-celled, distal side scarcely bent at join of weakly formed *Ts*. *Mspl* long, nearly straight, generally joined to *Ts* by the irregular bases of first row of cells under *M*₄. *Sc* prolonged through nodus for one or two 'cells' distance. Basilar and submedian spaces reticulated ; subtriangles free ; hypertrigonal spaces reticulated. Anal loop somewhat irregular, only 2-3 cells wide by 4-5 cells deep. Membranule

medium or nil. Anal triangle of male right-angled, strong, 3-5-celled, ending somewhat above anal angle, the latter strong, right-angled.

Front prominent, anvil-shaped (exceptionally, more or less rounded). Abdomen of male with prominent auricles, and strongly constricted at segment 3; that of female more cylindrical, segment 9 carrying a small projecting shelf armed with a set of teeth.

Type: *Telephlebia godeffroyi*, Selys.

The distinguishing character which separates this genus from all others of the group is the production of the subcosta beyond the nodus. Whether the apparent production of this vein in the imago is really a true production of the subcosta, or only an approximation to the appearance of it, caused by the arrangement of irregular postnodals into two regular rows, is a question that can only be satisfactorily answered by a study of the nymphal wing. Unfortunately this is not at present available. Some interesting evidence on this point is furnished by a study of the wings of the fossil *Æschnidium densum*, Hagen (Atlas to Handlirsch's 'Fossilen Insecten,' plate xlvii. fig. 16), in which also an apparent prolongation of the subcosta is noticeable, to a considerable distance further than in *Telephlebia*. But it will be seen at once in this figure that the dense crowding of cross-veins in the costal spaces is the real cause of this result; for, on the other side of the nodus, there appears an *exactly similar thin straight vein lying parallel to and between the costa and subcosta*, which from its very position cannot be claimed as any portion of a main longitudinal vein. It is well known that closely-set cells tend to straighten out in rows, after the manner shown by Needham in a well-known diagram*. The most advantageous position for this straightening to take place would be, of course, in a continuous line with the subcosta; and, if only two rows of cells existed beyond the nodus, that is also the natural (one might almost say, the only possible) position of straightening.

Further evidence on this interesting point may be obtained by comparing the nodal area of *Telephlebia* (Plate 8. figs. 21-24) with some variations found in the nodal area of *Austrophlebia* (Plate 9. figs. 17-20). Are these latter variations from the normal the last remnants of a denser habit of venation which *Austrophlebia* has eliminated—just as it has eliminated the cross-veins from its basilar space,—but which *Telephlebia* has weakly perpetuated? Or are they the beginnings of an attempt towards denser venation which has been successfully carried out in the case of *Telephlebia* in connection with the development of the pigment-band? The evidence is not conclusive, but the former alternative is supported by the consideration that *Telephlebia* appears to be the more archaic of the two forms, by reason of the retention of cross-veins in its basilar space.

It is, of course, possible that the subcostal vein in Odonata was originally branched or bifurcated near its extremity, and that the strengthening of the

* Needham in Proc. U.S. Nat. Mus. xxvi. (1903) p. 727.

upper branch by fusion at the nodus had led to the gradual decay of the useless lower branch. A very careful study of nymphal wings might decide this point, but I doubt if the evidence would be at all conclusive. The fact that the apparent prolongation through the nodus is always to be found associated with dense venation and generally also with pigmentation—and, again, that apparent prolongations occasionally occur in teratological specimens in the *Libellulinae* and *Corduliinae*, in which the wing is striated and broadened (thereby causing an increase in the number of rows of cells between some of the main veins)—suggests that the subcosta is not really concerned in the prolongation to any greater degree than any main wing-trachea may be considered to be concerned in the production of neighbouring cross-veins from its smaller tracheoles.

Two distinct species of the genus *Telephlebia* are known, one of which is widely distributed over Eastern Australia and shows four distinct regional or subspecific forms ; while the other is only known by two females from S. Queensland. They are :—

- Medium to large species ; *wings* with irregular brown band along costa ; *front* anvil-shaped ; *pterostigma* elongated ; *membranule* present. Venation fairly dense *T. godeffroyi*, Selys.
- Smaller and slenderer species ; *wings* without bands ; *front* only slightly anvil-shaped ; *pterostigma* short ; *membranule* absent.
- Venation open *T. asthenes*, n. sp.

TELEPHLEBIA GODEFFROYI, Selys. (Plate 3. figs. 1-5.)

Telephlebia godeffroyi, Selys, Bull. Acad. Belg. 1883 ; R. Martin, Mém. Soc. Zool. France, 1901, p. 242 ; R. Martin, *Æschnines*, Coll. Selys, fasc. xix. (1909) p. 141 (with figures of wings and appendages of male).

Four very distinct forms of this species occur. As these inhabit well-defined regions, and do not seem to be connected by transitional forms, I have no hesitation in describing them as subspecies. Their claim to specific rank cannot, however, be entertained for one moment by anyone who has carefully observed and collected in the different localities, even though striking differences are manifest by comparing any two of the subspecies. They may be separated as follows :—

1. { Superior appendages of male only slightly longer than [n. subsp.
inferior *T. godeffroyi brevicauda*,
" " " about twice as long as
inferior 2.
2. { Front very much anvil-shaped, quite black or dark brown [Selys,
above *T. godeffroyi godeffroyi*,
" less anvil-shaped, pale brown with a large round
dark spot above 3. [n. subsp.
3. { Thorax with slender humeral bands of cream-colour *T. godeffroyi cyclops*,
" with no humeral bands *T. godeffroyi tillyardi*,
[Campion, n. subsp.

The habitats of these four forms are very distinct, as follows :—

T. brevicauda. Mountains of Victoria and Kosciusko, N.S.W.

T. godeffroyi. Blue Mountains and coastal spurs ; New England Ranges, above 3000 feet, N.S.W.

T. cyclops. Mountain scrubs of Northern N.S.W. and S. Queensland, 1500–2500 feet.

T. tillyardi. Kuranda, Herberton, and Atherton districts of N. Queensland, 1000–4000 feet.

T. GODEFFROYI GODEFFROYI, *Selys*. (Plate 3. fig. 1.)

This form has been well described by both Selys and Martin (*loc. cit.*). Unfortunately, however, Martin, while figuring the typical male appendages, seems to have used a specimen of *T. godeffroyi brevicauda* (probably from Alexandra, Vic.) in re-writing his description ; for he says of the appendages “l'inférieur presque aussi long,” in spite of his figure. The following are the distinguishing points of this form :—

Wings.—*Triangles* of medium length (about 3·5 mm.), that of fore-wing much narrower than that of hind-wing, both usually 5-celled in ♂, 5–7 in ♀ ; basal side of triangle slightly less than 1 mm. distal from arculus (Plate 8. fig. 17). *Pterostigma* averaging 3·8 mm., ♂ rose-brown, ♀ pale brown, slightly biconvex, about 0·8 mm. wide (Plate 8. fig. 13). *Membræ* white, fairly large, 1 mm. in fore-, 2 mm. in hind-wing (Plate 8. fig. 29). *Costa* pale brownish. On all four wings the brown band covers the basal three-fourths of the subcostal space, most of the basilar space (its lower distal portion excepted), all the sub-radial space up to nodus ; at the nodus it becomes a large dark blotch 2–2·5 mm. in width and depth, lying distal from nodus ; thence onward the band fills the space between R_1 and M_1 up to pterostigma and the distal portion of the costal space right up to tip of wing ; the strong brace is usually suffused, and the band sometimes runs under the stigma also to the tip. *Nodal Indicator* $\left\{ \begin{array}{l} \text{circ. 30, circ. 20} \\ \text{circ. 20, circ. 22} \end{array} \right\}$. The most usual form of venation at nodus is shown in Plate 8. fig. 21.

Head.—*Face* slightly hairy, pale shiny brown all over, *labrum* slightly brighter. *Front* strongly anvil-shaped, the upper portion dark brown all over, shading to black at the angle (Plate 8. fig. 27).

Thorax.—Rich chocolate-brown above, with pale cream- or straw-coloured dorsal and interalar ridges ; *humeral bands* straight, distinct, pale straw- or cream-colour, about 0·5 mm. wide, bounding the rich brown dorsal area on each side ; sides dull brownish, not much paler than above, with indications of a pale stripe along sutures. *Legs* fairly short, profemora nearly black, other femora pale brown with black elbows ; tibiae pale brown, tarsi medium brown.

Abdomen.—♂ 1–2 swollen, 3 pinched, 4–10 medium cylindrical.
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♀ 1-2 much swollen, 3 only slightly pinched, 4-10 cylindrical, thicker. General colour very dark brown, tending to black, especially at distal ends of segments, and more especially on 6-9.

Appendages.—♂. *Superior* averaging 4 mm., *inferior* only about half as long; superiors slightly waved, converging but not meeting at tips; inferior narrow subtriangular, hollow, upcurved; colour semitransparent brown (Plate 8. figs. 7-8). ♀ short, 0.6 mm., straight, pointed, pale brown. Under segment 10 of ♀ is a projecting dentigerous plate or shelf, somewhat incised medially, with small black teeth arranged in an irregular set of 3 or 4 on each side of the median incision (Plate 8. fig. 25).

Types: ♂ ♀, Coll. Selys.

Habitat. Typical *T. godeffroyi* occurs not uncommonly on all the central mountain-ranges of Eastern N.S.W., viz. Blue Mountains and their southern spurs as far as Moss Vale. It also occurs occasionally at a lower elevation of 600 to 1000 feet in the hills between Sydney and the Hawkesbury River. On the New England Ranges it is rare except at very high elevations, *e. g.* at Guy Fawkes, 4000-5000 feet. It probably extends to the Darling Downs, though I have no records of it from Queensland. End of November to February.

The density of the brown bands on the wings is subject to much variation. In most specimens the band is dark and continuous, the cross-veins appearing pale on the band. This condition intensifies with age. At Ebor (Guy Fawkes), N.S.W. (4000-5000 feet above sea-level), I found, besides this typical form, a form in which the band was extremely light and in places scarcely discernible. The less mature specimens simply showed the band as pale saffron, crossed by dark brown veins; in the maturer specimens the band tends to break up and the pigment collects around the cross-veins, leaving clear spaces in between. This colouring corresponds with a difference in habit. Usually the insect keeps to the steep rocky parts of deep gullies, hiding under rocks and in caves during the day, and only appearing towards evening to indulge in its ghost-like flight. But at Ebor it had found its way up to the tops of the gullies, and was evidently becoming accustomed to the more open conditions, for I often captured it flying in company with *Austroeschna multipunctata* during the daytime. I propose to call this form variety *hyalina* (Plate 3. fig. 2).

T. GODEFFROYI BREVICAUDA, n. subsp. (Plate 3. fig. 3.)

The following are the chief points of difference from typical *T. godeffroyi*:—

Size somewhat smaller, especially in ♂ (see Table of Comparison, *infra*). *Front* uniformly brown above, but not so dark; the anvil-point touched with black, and almost as sharp as in the type-form. *Wings*.—*Costa* very pale,

transparent whitish or yellowish. *Pterostigma* shorter and narrower, 3 to 3·5 mm., not so biconvex, only 0·6 mm. wide (Plate 8. fig. 14). *Venation* more open. Brown bands similar to those of type, but usually paler. *Membranule* white, slightly longer (2·2 mm.) and distinctly narrower than in type-form (Plate 8. fig. 30). Usual nodal venation as shown in Plate 8. fig. 22. *Triangles* rather shorter, with basal side *very close up to arculus* (Plate 8. fig. 18).

Thorax with humeral bands slightly paler and broader; legs with tibiæ darker brown. Abdomen as in type-form. Appendages of ♂:—*Superior* only 2·8 mm. long, nearly straight, converging; *inferior* shaped as in type-form, reaching to about 1 mm. from tips of superiors (Plate 8. figs. 9–10).

Though the males of this and the type-form are so distinct, it would be impossible to separate the females except on the general paler appearance of a series of *T. brevicauda* ♀, compared with a series of the type ♂.

Types: ♂ ♀, Coll. Tillyard. (Mount Macedon, Victoria; taken by Mr. G. Lyell.)

Habitat. Mount Macedon and Gippsland, Victoria. Kosciusko and Southern Alps, N.S.W. 2000–5500 feet.

It appears to be much rarer than the type-form. Though it may be taken sparingly around Kosciusko every year, yet its appearance on Mount Macedon is exceedingly capricious, and there can be little doubt that in the colder climate the larva only develops very slowly. On January 1st, 1906, my friends Messrs. G. Lyell and S. Angel found it in swarms round about the waterfall on Mount Macedon. The day was exceedingly hot, and the dragonflies kept bathing in the spray or settling half torpid on the damp rocks. Many were caught by hand, and I received a fine series of about twenty specimens. Though a careful watch has been kept for it, it has not appeared in the same locality since. Along the gorges of the Upper Snowy River, on the slopes of Mount Kosciusko, I found it very sparingly, and have received one or two specimens from collectors each year. It emerges at the end of December, and is probably over early in February.

With regard to the shorter superior appendages of the male, it is a very interesting fact to record that males of the type-form are often taken with their superior appendages (either one or both) broken off just at a point about 1 mm. beyond the tip of the inferior. Viewed laterally, there is a slight curve from this point to the tips, and I am of opinion that the appendages are broken when the male is attempting to seize the female. At that time both indulge in a wild chase up and down the creeks, and so rapid are the evolutions, and so difficult the struggle for mastery on the part of the male, that it is not to be wondered at if the slender tips break off. The broken appendages are just as useful for holding the female, since I have once or twice taken a pair *in cop.*, in which the male had a broken

appendage. It seems therefore extremely probable that the longer appendage is the more archaic form, and that the shorter one of *T. brevicauda* has either been evolved gradually from it as a more useful form, or has arisen as a sudden mutation, or, possibly, as the direct inheritance of an acquired character, in the Lamarckian sense.

T. GODEFFROYI CYCLOPS, n. subsp. (Plate 3. figs. 4-5 ; Plate 4. fig. 3.)

This subspecies differs from the type-form as follows:—

Size considerably larger (see Table of Comparison, *infra*). *Front* much less anvil-shaped, more rounded, pale brown above, with a large black rounded blotch (Plate 8. fig. 28). *Wings*:—broader and more bluntly rounded at tips. *Pterostigma* longer, 4.5 mm., much broader, quite 1 mm. wide, not very convex; colour straw, shading to rose in mature specimens (Plate 8. fig. 15). *Triangles* more elongate, 5-7-celled, with basal side quite 1 mm. or more distal from arculus (Plate 8. fig. 19). *Venation* dense. Brown bands very dark and irregular, the part between base and nodus broken up into two or three thick dark patches connected by narrower and paler strands; nodal blotch very dark and large, about 3 mm. long and deep; distal half of band medium brown, regular, not passing *under* pterostigma. *Membranule* 1.5 mm., white, exceedingly narrow (Plate 8. fig. 31).

Venation at nodus as shown in Plate 8. fig. 23.

Thorax.—Almost black above, with straw-coloured dorsal and interalar ridges; *humeral bands* very narrow, pale brown, not very distinct; sides greyish brown, with a short dark line fringing the humeral band close to wings. The dark dorsal and pale lateral areas of the thorax are marked off very distinctly at the humeral bands. *Legs* pale brown except for conspicuous black patches on elbows.

Abdomen.—Shaped as in type-form, but with a distinct pattern of pale straw-brown overlying the dark brown ground-colour. 1, pale brown except for a dorsal apical squarish spot; 2, pale on sides and auricles of ♂; 3 with pale base and pale dorsal stripe, indistinct; 4-7 with pale lateral basal subtriangular blotches pointing downwards and outwards. In ♂, 10 distinctly more sharply tubercled dorsally than in type-form. The pale pattern is less distinct in ♀, and may become obliterated with age. Appendages of ♂.—*Superior* 4.4 mm., very similar to those of type-form, but converging so as to meet, and ending in a tiny inward spine; *inferior* as in type-form. In the ♀ the dentigerous shelf of segment 10 is not so incised medially as in type-form, and the teeth are somewhat more regularly arranged.

Types: ♂ ♀, Coll. Tillyard. (♂, Dorrigo, N.S.W. ♀, Mount Tambourine, Q.)

Habitat. Mountain scrubs of northern N.S.W. and southern Queensland. Apparently rather rare. December to February.

T. GODEFFROYI TILLYARDI, n. subsp., *Campion*.

For complete description see Appendix B.

This subspecies is very close to *T. cyclops*, but differs from it in its somewhat greater size, its longer pterostigma, and the complete absence of the humeral bands of the thorax.

Type: ♀ unique; British Museum.

Habitat. Kuranda to Herberton, N. Queensland. 1000-4000 feet. January.

Mr. F. P. Dodd has occasionally taken females of this rare form in the districts named, but the only specimen whose location is at present certain is the type. The male has never been taken, nor have I any specimens in my own collection.

Table of Comparison for the Subspecies of *T. godeffroyi*, Selys.

	<i>T. godeffroyi</i> .	<i>T. brevicauda</i> .	<i>T. cyclops</i>	<i>T. tillyardi</i> .
♂. Total length	64-69 mm.	60-64 mm.	72 mm.	—
Abdomen	50-55	47-50	57	—
Fore-wing	40-42	39-40	47	—
Hind-wing	39.5-41.5	38.5-39.5	47	—
Expanse	82-87	78-82	99	—
♀. Total length	63-67 mm.	60-67 mm.	68 mm.	70.5 mm.
Abdomen	49-53	45-52	53	54
Fore-wing	45-47	43-45	49	53
Hind-wing	45-47	43-45	49	53
Expanse ..	94-98	89-93	102	109
Pterostigma	3.6-4 mm.	3-3.5 mm.	4.5 mm.	5.5 mm.
Membrane of hind-wing.	2 mm., white.	2.2 mm., white, narrower.	1.5 mm., white, very narrow.	brownish white.
Humeral bands of thorax.	straight, narrow.	slightly broader.	narrower.	absent.
Superior appendages of ♂.	4 mm.	2.8 mm.	4.4 mm.	—
Coloration of front ...	uniform dark brown or black.	uniform brown.	brownish with large round black spot.	large oval spot, blackish.
Dentigerous plate of seg. 10, ♀.	medially incised.	medially incised.	more regular.	more regular.

Life-History of Telephlebia godeffroyi godeffroyi, Selys.

During the last eight years I have collected a considerable amount of information concerning the life-history of this remarkable Dragonfly, but many gaps still remain to be filled in.

The insect is of a distinctly crepuscular habit, being seldom met with until late in the afternoon, and then only in the deep shady gullies. Very often it is flushed from a twig or bush where it is resting, and will make off for twenty or thirty yards, and re-settle in any suitable dark place. It has a great fondness for caves and shady interstices of rocky escarpments. When

settled, its protective coloration makes it practically invisible. About 5 P.M. the insects set out on their hunt for mosquitoes, which they catch with marvellous agility. At this time their flight is rapid, bewildering, and ghost-like, and they appear to be more like the shadow of a dragonfly than the reality. They career round bushes and trees with their mouths wide open, swallowing midges and mosquitoes with wonderful ease and agility. These wild flights continue until after dark. I have caught specimens (more by luck than anything else) flying round bushes as late as 8.30 P.M. Specimens are also not uncommonly taken at light between 8 and 12 P.M., and I have two specimens which flew into a house on the Blue Mountains, attracted by a lamp.

The female oviposits by herself in the late afternoon, seeking the darkest corners of the rocky pools. At such times her flight is furtive and very restless. The deposition of the eggs is carried out in the same manner as in the case of *Austrophlebia costalis*, and the description given would fit either species equally well, except that *Telephlebia* behaves in a more timorous manner even than *Austrophlebia*. The slightest sound or disturbance is sufficient to send the insect high up into the trees. I have never yet succeeded in capturing an ovipositing female.

When the young larva hatches out, it probably hides for some time in the trash and débris of the pools. Later on it develops remarkable habits, which may be inferred from my observations on the only living larva so far discovered. This larva was found by me in October 1906 while dredging in the Leura Cascades. In a net full of sand and débris collected close under the bank of the creek in a rapid part of the cascades, I found a slender slimy-looking larva of most peculiar aspect. The first glance suggested that it was the larva of a fairly large Agrionid without the caudal gills. On examining it, however, the size of the head and eyes, and the presence of Anisopterid appendages, showed me that it was an *Æschnine* larva. By a process of exhaustion I knew that it must be the larva either of *Austropetalia* or *Telephlebia*, since all the other *Æschnid* larvæ occurring there were known to me. Later on, the discovery of the exuviae of *Austropetalia* with the insect just emerging, in Nov. 1908, convinced me that it must belong to *Telephlebia*. But absolute certainty was not attained until Jan. 1912, when I discovered the exuviae and emerging imago of *Telephlebia* at Ebor (Guy Fawkes), N.S.W., and found that it agreed exactly with my Leura larva.

This larva was about half-grown, only 19 mm. long, and appeared to be mainly head, the thorax and abdomen being very slender, while the head was quite 4 mm. wide from eye to eye. When handled it was found to be slimy. It was taken home and placed in a small cylindrical observation-jar, 6 inches high by 5 inches diameter, provided with a sandy bottom, growing water-weeds, and several sticks jutting out from the water. Next morning I found it sitting at the top of a stick, four inches above the water. I picked

it up and dropped it into the water, when it swam off and clung to a stick, only to climb up out of the water shortly afterwards. Thus it remained for some days, eating nothing. When I approached it, it appeared to be eyeing me guardedly, and always slipped round to the opposite side of the stick, still watching me from the corner of its projecting eye. By walking round the jar I could make it circle the stick, and it never for a moment left off watching me. I was irresistibly reminded of the similar habits of the monitor lizard.

A few days later I returned home about 11 P.M., and went to look at the larva. I could not find it either in the water or on the stick. A damp streak showed me that it had climbed over the edge of the jar, and had probably fallen off the table. A long search followed all over the room. Finally, I discovered a large spider (locally called a "tarantula") making off across the floor with a bundle done up in silk. The spider released the bundle when I attacked him, and disappeared into a crevice of the wooden flooring. Inside the silken bundle I discovered my larva, apparently not much the worse for the adventure. I removed the silk, which stuck very closely to his slimy skin, and replaced him in the aquarium, which I covered over for the night. Next day I improvised a covering of mosquito-netting to fit closely over the jar, and replaced him in it.

So far the larva had eaten nothing. I now introduced live flies into the jar, and had the satisfaction of finding that he ate a portion of one of these. Doubtless he ate others which I did not see, for in a few days he grew considerably stouter, and I saw that an ecdysis was approaching. This ecdysis was carried out on the stick, out of the water, and I secured the cast skin.

The larva now began to grow rapidly, not lengthening very much, but broadening out until the thorax and abdomen were of distinctly *Æschnine* form. The wing-cases began to appear, and I had great hopes of rearing it. But an untimely end was in store, for I foolishly left the covering off the jar one night; the larva made his escape, and this time doubtless the spider made no mistake, for I never saw him again. The most interesting differences between the half-grown larva and the full-grown one, as represented by the exuviae from Ebor, were the comparative slenderness of the thorax and abdomen and the greater hairiness of the labium, though this latter character probably does not show itself as fully on the exuvial labium as it would in the living full-grown larva. The following description applies to the Ebor specimen which I have before me, and which is figured in Plate 2. fig. 4.

Total length 27.5 mm., *greatest breadth* 7 mm. across eyes. Colour very dark brown, without any very apparent pattern. *Head*.—5 mm. long, with prominent rounded *labrum* and *front*, large laterally projecting *eyes*, and large postorbital lobes rounded and irregularly notched and roughened; nearly the whole surface, except the eyes, shagreened with tiny and numerous warts and dots; *occiput* with an upstanding irregular tubercular ridge just

behind level of eyes, carrying hairs. Labium with fairly broad and long mentum, 6.5 by 4 mm., reaching to well between pro-coxæ (Plate 6. fig. 2); upper part of mentum carrying short downy hairs all over; lateral lobes short, carrying close-set hairs on the outer margin; movable hook 1.4 mm., slender, pointed; inner margins very finely denticulate or crenulate; apex narrow, rounded, with very slightly nodding outer angle; median lobe projecting very slightly, obtusely rounded off (Plate 5. fig. 2). Thorax.—Prothorax short, 3.5 mm. wide, with projecting lateral spines; meso- and metathorax 4 by 4.5 mm., rather small; hind wing-case 5 mm., greatest breadth 2 mm., tip broadly rounded. Legs of medium size, strongly built, with femora irregularly roughened and flattened. Abdomen.—15.5 mm. long; greatest breadth 5 mm. at segment 5; segments 8–10 very tapering; well rounded above, fairly flat beneath; the whole dorsal surface finely shagreened. No dorsal spines, but minute apical ridges carrying hairs on segments 3–9. Segment 10 raised dorsally into a large blunt upstanding tubercle. Appendages rather remarkable, the superior being a sharply down-curved spine, not so long as inferiors and carrying above it a strong blunt tubercle about midway (possibly this is the involucre of the male imaginal inferior appendage); the two inferiors are longer and stronger spines, 1.5 mm., only slightly curved inwards at tips, lying close together, carrying underneath a few strong hairs or fine spines (Plate 7. figs. 2, 14). Involucra of male superior appendages are straight spines 1 mm. long, lying at the level and on either side of the superior larval appendage.

Larval Type: ♂, unique (Ebor, N.S.W., Jan. 6th, 1912). Coll. Tillyard.

This very remarkable larval form is probably one of the most archaic *Æschnine* types still in existence. In the slenderness of its thorax and abdomen it may perhaps be considered specialized, but in the form of its labium, with its narrow and finely denticulate inner margin of the lateral lobes—which also lack the strong angulated and projecting tip of the more specialized *Æschninæ*—it shows distinct relationship to *Petalia*, and hence also to the *Gomphinæ*. The anal appendages appear to be specialized into a strong united down-curving spine of great value to the insect for holding tightly to twigs. But the most remarkable thing about it is undoubtedly its preference for living out of the water. Possibly the fine warts and dots of the shagreened skin support the openings of slime-glands, which may help the insect to keep moist while out of water. An even coarser shagreening is noticeable in the exuviae of *Austropetalia patricia*, and it would be interesting to obtain the living larva, and to see whether its habits are similar to those of *Telephlebia*.

It is very remarkable that two such archaic forms as *Telephlebia* and *Petalura* should, in their larval stages, depart so far from the normal manner of living in the water; the one preferring to live on twigs out of the water,

while the other lives in tubes constructed in mud or peat, and is very probably able to breathe air directly. Such habits have nothing in common except divergence from the normal, and probably represent two extreme lines of specialization by larvæ that were ousted from their original habitat in the water by more progressive forms. They cannot, to my mind, be used as arguments in favour of the view that the ancestors of our Odonata once possessed land-living larvæ. There are other more cogent arguments for that view.

TELEPHLEBIA ASTHENES, n. sp.

♂ unknown.

♀. *Total length* 48·5 mm., *abdomen* 37·5 mm., *fore- and hind-wings* 35 mm. each; *expanse* 73 mm. (Plate 4. fig. 4.)

Wings.—Hyaline, bases lightly saffroned for 3–4 mm. *Neuration* open, dark brown. *Triangles* of medium length, 3–4-celled, that of hind-wing slightly the broader of the two; basal side of both 1 mm. distad from arculus (Plate 8. fig. 20). *Basilar space* with 3–5 cross-veins, *submedian space* with 6–7, the last forming a weak subtriangle. *Hypertrigonal space* with 3–4 cross-veins. *Nodal Indicator* $\left| \begin{smallmatrix} 19, & 14 \\ 14+15, & 14 \end{smallmatrix} \right|$. *Sc* prolonged beyond nodus for only one complete cell's length, very regular (Plate 8. fig. 24). *Pterostigma* short, 2·0 × 0·8 mm., biconvex, pale brownish (Plate 8. fig. 16). *Membranule* practically obsolete (Plate 8. fig. 32). *No brown bands on wings*.

Head.—Shiny brown, slightly paler on labrum and between vertex and frontal ridge. *Eyes* large, rather flattened, meeting for 2·5 mm.

Thorax.—Short, small; almost black, with pale yellow dorsal ridge, two very distinct brown dorsal patches, and, on each side, a lemon-yellow lateral band; underside grey-brown. *Legs* brown, *tibiae* with numerous spines.

Abdomen.—1–2 swollen, 3 scarcely pinched at all, 4–10 narrow cylindrical, flattened from side to side. *Colour* very dark brown; a narrow basal dorsal mark on 2, pale brownish, pointed distally; apical portions of 3–6 paler dorsally. *Ovipositor* reaching to middle of 10, upcurved. *Dentigerous shelf* of 10 not medially incised, rather squarish, with two lateral sets of 3–4 small teeth (Plate 8. fig. 26).

Type: ♀, Coll. Tillyard. Taken by Mr. E. J. Dumigan at Killarney, S. Queensland, on Jan. 8th, 1914.

An immature and somewhat damaged female, now in the Queensland Museum, Brisbane, taken by Mr. H. Hacker at Mount Tambourine, S. Queensland, on Nov. 4th, 1911, is the only other known specimen of this rare species. It was not sufficiently mature or complete to form a satisfactory type. It is somewhat larger than the type; wings 37 mm., with one or two more antenodals.

This species is very distinct from *T. godeffroyi* by its hyaline wings without trace of bands, its short pterostigma, open venation, absence of membranule, very regular prolongation of subcosta, smaller size, and somewhat different coloration. It appears to be a specialized asthenogenetic offshoot from the main stock, and is one of the smallest *Æschninae* known to me.

B. HYLOCHROME SERIES.

Colour black or dark brown, marked with spots, blotches, and bands of bright yellow or green, yellowish-green, bluish-green, or grey; wings always completely hyaline. This colour-scheme is very striking during flight, but gives great protection to the resting insect, which partakes of the particoloured scheme of the surrounding forest. Flight diurnal.

Genera :—

- | | |
|---|---|
| 1. Basilar space reticulated..... | 1. DENDROÆSCHNA, n. g.
(Type, <i>Caliaschna conspersa</i> , Tillyard.) |
| 2. Basilar space free. | |
| 2a. Female with a dentigerous plate on the under-
side of segment 10 | 2. AUSTROÆSCHNA, Selys. |
| 2b. Female with dentigerous plate obsolescent, but
with a sharply-projecting dorso-apical spine
on segment 10, between appendages | 3. NOTOÆSCHNA, n. g.
(Type, <i>Austroæschna sagittata</i> , Martin.) |

Genus 1. DENDROÆSCHNA *, n. g.

Neuration fairly open; median, submedian, and hypertrigonal spaces reticulated. *Rs* forked well before level of pterostigma; *Rspl* separated from lower branch of fork by a single row of cells. *M*₄ distinctly waved in its distal half, bending away from *M*₃ so as to increase the intervening cell-rows from one to two. Anal triangle of ♂ wide; membranule small. *Mspl* one row of cells below *M*₄. Nodus placed well beyond halfway between base and pterostigma. Pterostigma very strongly braced, short. Triangles short, wide, 2-3-celled. *Sc* normal.

Eyes large and very contiguous. Front exceedingly wide, elevated into a large semicircular ridge. Vertical tubercle almost obliterated; ocelli nearly touching each other. Antennæ very wide apart. Female with a dentigerous plate under segment 10.

Type: *Caliaschna conspersa*, Tillyard.

I propose this new genus for the reception of the type-species only, since it is evidently not congeneric with the other known species of *Caliaschna*. The fact that the type of this latter genus (*C. microstigma*, Schneid.) occurs

* Greek, δένδρον, a tree.

in Asia Minor, while *C. conspersa* is confined to New South Wales, led me to compare the two insects carefully, when important differences at once became apparent. As to the question whether the other species described by Martin under *Caliaeschna*, and occurring in various parts of India and the East Indies, are also congeneric with the type, I am unable to give a definite answer for lack of the necessary material. The chief differences between *Caliaeschna*, Selys, and *Dendroaeschna*, n. g., are as follows :—

1. In *Caliaeschna* the eyes are "peu contigus." In *Dendroaeschna*, on the contrary, they are very contiguous and large, almost obliterating the post-orbital triangle.

2. The remarkable form of the front in *Dendroaeschna*, with the consequent closeness of the three ocelli together, the obliteration, almost, of the vertical tubercle, and the wide separation of the antennæ, is far more specialized than any tendency in the same direction observable in *Caliaeschna*.

3. In *Caliaeschna* the nodus lies about halfway between base and pterostigma in fore-wing, nearer to the base in hind-wing. In *Dendroaeschna* the nodus lies distally from the middle in both wings.

4. In *Caliaeschna* the pterostigma is not braced ; in *Dendroaeschna* it is very strongly braced.

DENDROÆSCHNA CONSPERSA, Tillyard, n. sp. (Plate 4. fig. 5.)

Caliaeschna conspersa, Tillyard, Proc. Linn. Soc. N.S.W. xxxi. (1906), Part 4, p. 727 ; Martin, Æschnines Coll. Selys, fasc. xix. (1909) p. 112.

Types : ♂ ♀, Coll. Tillyard.

Habitat. New South Wales, Sydney district and lower Blue Mountains ; also Illawarra district and Mittagong. I have also taken the larva, but not the perfect insect, on Rocky Creek, Nandewar Ranges, near Bingara, N.S.W.

Life-History.—This species appears very late in the season, at the end of February or beginning of March. The immature imagines fly straight up into the trees, which become their home for the rest of their existence. Consequently, one can always find throughout March and April very many more exuviae than imagines. At Heathcote, N.S.W., on April 12th, 1909, I found the exuviae thick on every stick and stem jutting out from the creek. On one twig I gathered no less than twelve exuviae, while in some cases they had climbed on to one another's backs for lack of room. Most of the insects had evidently been out for some time, but a few were still emerging, and I secured a long series of perfectly fresh clean larval skins. Though it was a warm sunny day, I only captured six imagines.

As is usual with those Dragonflies which live in the forest, the imagines remain immature for a long time, especially the females. During the day they may be seen flying high up round the trees, alternately soaring and

darting. Every now and then they descend to chase small gnats and flies, and may then be captured with a little luck, though they are very skilful and quick at dodging the net. Later on, in the afternoons, and especially towards the end of May, when they are mature, these insects descend to the creek-bed and fly very rapidly up and down. The females oviposit in May and June, and even on warm days in July. Their method is to select some old and half-rotted piece of wood dipping into the water, or occasionally a damp mossy rock, on which they settle. They then proceed to lay their eggs one by one into the damp wood or moss. This is done deliberately and slowly. I have watched a female stay for over twenty minutes in one spot ovipositing. They are, however, extremely watchful, and the slightest movement sends them dashing off. I never succeeded in catching an ovipositing female, though I have taken them while they were examining suitable nooks and corners for laying.

Probably the eggs do not hatch until the spring, for in November and December any larvæ taken are exceedingly small. The young larva is very hard-skinned, being absolutely black and very spiny. After an ecdysis the larva is green and delicate for a short time, then rapidly darkens, and in less than an hour is hard and black again. It lies on twigs, amongst débris, or hiding on the underside of flat rocks. It is very active, and can run rapidly. If handled, its sharp spines can be used with considerable effect, and are, no doubt, a strong defensive weapon against its natural enemies. It is a voracious feeder, attacking other Odonate larvæ and even its own species without discrimination. Ecdyses succeed one another rapidly during the summer, usually at intervals of a fortnight or less, according to the supply of food. About the end of February the larva becomes torpid for some days, and the skin is excessively hard and tough. Finally, it emerges by crawling up a stick or stem, usually in the early morning.

Larva.—The full-grown larva is not absolutely black, but has a ground-colour either of black or very dark brown, very intricately mottled all over with paler brown.

Total length 30–34 mm.; *greatest breadth* 7 mm. across eyes and also across segment 7 of abdomen. *Head*.—5·5 mm., with prominent *eyes*, *front*, and *labrum*; *antennæ* 2·2 mm. apart at bases; *postocular lobes* large, rounded, with a projecting lateral spine on each side, 5·5 mm. apart. *Labium*.—*Mentum* 6 mm. long, 4·5 mm. wide distally, narrowing basally and reaching back to between mesocoxæ, where it is only 2·5 mm. wide. *Median lobe* very slightly convexly curved, with a row of short stiff hairs. *Lateral lobes* with apex truncate, outer angle slightly rounded, inner angle almost a right angle, inner border very finely crenulate; movable hook strong, curved, 1·2 mm. (Plate 5. fig. 7). *Thorax*.—*Prothorax* 2 × 4·5 mm., with prominent humero-lateral spines, and below them, on each side, two sublateral spines or prominences close together (Plate 6. fig. 3). *Meso-* and

metathorax 4.5 × 6 mm., irregular, with fairly prominent lateral tubercles; *wing-cases* 6 mm., parallel. *Legs* short, fairly strong, much spotted with pale brown on a black or dark brown ground-colour; femora regular, not much flattened. *Abdomen*.—Elongate-oval, well arched above, flattish beneath, 3 mm. wide at 2, then widening to 7 (7 mm. wide), then curving in to 2.5 mm. width at 10. No dorsal spines. Strong *lateral spines* on 6–9, those of 6 smallest, the others increasing to 9. *Appendages*.—*Superior* short, 1.3 mm., depressed, truncate, carrying at its truncated tip two small sharp outer teeth and two blunt median teeth, close together. In the ♂ the involucre of the inferior imaginal appendage overlies it as a flat triangular projection; in both ♂ and ♀ the involucres of the superior imaginal appendages lie on each side of it as fairly straight and pointed spines, 1.1 mm. *Inferiors* 2.5 mm., broad-based strongly triquetral spines, very sharp, with slightly incurved tips. In the living larva these spines can all be pressed together to form a powerful weapon of defence (Plate 7. figs. 3, 15). *Ovipositor* of ♀ nymph of medium size, reaching just beyond end of segment 9.

Larval Types.—♂ ♀, Coll. Tillyard. (Heathcote, N.S.W., April 10th, 1909.)

The perfect insect is exceedingly beautiful on the wing, its large glowing emerald eyes and the numerous bright green spots on its thorax and abdomen giving it a very striking appearance. It has already been fully described both by M. René Martin and myself (Proc. Linn. Soc. N.S.W. xxxi. (1907) p. 729). Phylogenetically, it seems to hold the same relationship to *Austroæschna* that *Telephlebia* does to *Austrophlebia*. There is no doubt that the “aphantochromes” are more archaic than the “hylochromes,” and that the particular line of specialization of the latter has led to their holding, in Australia, the dominant position attained in a somewhat similar manner in the Holarctic Region by *Æschna*, itself an archaic genus. But there can be little doubt that this development has been mainly due to the absence of competition with the larger and stronger species of *Æschna*, rather than to any intrinsic superiority; for our only species of the latter genus, *Æ. brevistyla*, is more widely spread and commoner than any of the “hylochromes,” and its voracious larva takes heavy toll on the latter wherever they occur together.

Genus 2. AUSTROÆSCHNA, Selys (*a me restrictum*).

Neuration open; median space free, submedian and basilar spaces with a few cross-veins. *Rs* forked well before level of pterostigma; *Rspl* separated from lower branch of fork by a single row of cells. *M*₄ distinctly waved in its distal half so as to increase the intervening cell-rows between it and *M*₃

from one to two. Anal triangle of ♂ right-angled, strong, 2-3-celled; membranule small. *Mspl* one row of cells below M_4 . Pterostigma strongly braced, of variable length. Triangles of medium length, usually 3-celled. *Sc* normal. Eyes large, contiguous for some distance. Front of variable width, rounded, not raised much above level of eyes; antennæ and ocelli normal in position; vertical tubercle present. *Female with a dentigerous plate under segment 10* (Plate 5. fig. 6).

Distribution confined to the Australian Region.

Type: *Austroeschna parvistigma*, Selys.

If the above definition of the genus, as now proposed by me, be accepted, it will be necessary first of all to remove from it the two non-Australian species included by Martin. These are *A. intersedens*, Martin (*Æschnines* Coll. Selys, fasc. xix. p. 101), from the Khasia Hills, and *A. milnei*, Selys, from Japan. Neither species is known to me, but there can be little doubt of their generic distinctness. The figure given by Martin for *A. intersedens* shows an absolutely unbraced pterostigma, a condition quite unknown in any true *Austroeschna*. *A. milnei* is only known from the female, and there are probably equally strong grounds for excluding it. Martin says nothing about its stigma being braced. On zoo-geographical grounds alone, it would be hard to accept it as congeneric with our natural Australian group of species.

It is also necessary to exclude, for removal into a new genus, the very remarkable species *Austroeschna sagittata*, Martin, which is a more highly-specialized form both in larva and imago.

Austrophlebia costalis, Tillyard, originally also included in this genus, has already been removed into a new genus in the "aphantochrome" series.

With these restrictions, there remain eleven species in the genus, to which will be added, in this paper, a twelfth. As these eleven have all been well described by Selys, Martin, Förster*, and myself, I shall content myself simply with describing the new species and the life-histories of those species which I have worked out, adding for reference a comparative table of the more striking differences.

The twelve species included in the genus *Austroeschna*, as restricted by me, fall naturally into two groups, according to their coloration and habits. These two groups do not, however, appear to me to be deserving of generic rank. They are:—

- I. Species which have developed a pattern of green, yellow, or greenish-blue markings on a dark brown ground, and with it have also formed the habit of settling in the foliage of bushes and trees where their colour protects them.

* Förster's genus *Dromæschna*, proposed for *A. forcipata* and *A. weiskei*, has nothing to recommend it, and is here re-absorbed into *Austroeschna*.

II. Species which have developed a pattern of grey or pale brownish on a black or almost black ground, and with it have formed the habit of resting on the dark trunks of trees or on burnt stumps. Their flight is essentially weaker and less sustained than that of the species in Group I., and they spend much more time in resting.

GROUP I.	GROUP II.
<i>Austroeschna tripunctata</i> , Martin.	<i>Austroeschna parvistigma</i> , Selys.
„ <i>weiskei</i> , Förster.	„ <i>multipunctata</i> , Martin.
„ <i>forcipata</i> , Tillyard (= <i>severini</i> , Förster).	„ <i>atrata</i> , Martin.
„ <i>unicornis</i> , Selys.	„ <i>anacantha</i> , Tillyard (= <i>aspersa</i> , Martin).
„ <i>inermis</i> , Martin.	„ <i>tasmanica</i> , n. sp.
„ <i>longissima</i> , Martin.	„ <i>victoria</i> , Martin.

The table on p. 48 gives the chief differences between the twelve species, and will be found sufficient for their determination. Except in the case of *A. victoria*, which I have not seen, the measurements given are the average of series examined by me, and are subject to a variation of about $\pm 4\%$. The colours also are those of mature specimens, wherever possible; those of *A. weiskei* are probably not fully matured. All measurements are in millimetres.

AUSTROÆSCHNA PARVISTIGMA FLAVOMACULATA, n. subsp.

♂ unique. *Total length* 61 mm., *abdomen* 47 mm., *fore-wing* 38.5 mm., *hind-wing* 37.5 mm. It differs from the type-form as follows:—

1. *Coloration of head* black, marked with bright yellow, viz. two large round spots on top of front, a large patch on either side of front close above post-clypeus; almost the whole of the post-clypeus bright yellow; two large geminate subtriangular spots on labrum, a small spot on genæ; labium reddish black.

2. *Coloration of thorax* dark brown, with yellow markings, placed as in type-form, but larger and more conspicuous; markings of sides tending to lengthen out to curved bands. The russet of the middle and hind femora much less developed than in type.

3. *Abdomen* almost black, with yellow markings, all larger and more conspicuous than in type-form. Dorsal spots of basal halves of 3–7 close together and large, isolating between them a black cross.

4. *Segment 10* much broader apically, quite 3 mm.; apical yellow spots large and wide apart. Hence:—

5. *Superior appendages* differing in shape from those of type, being shorter, 3.7 mm., very wide apart at bases, thence converging to tips; distinctly bent at middle so as to appear almost broken; basal halves much

Comparative Table for the Genus *Austroeschna* (Imagines).

AUSTROESCHNA	Total length	Aldo-men.	Hind-wing.	Ptero-stigma.	Thoracic pattern	Abdominal spots	Superior appendages ♂	Inferior appendages ♂	Appendages ♀	Ovipositor reaching to	Segment 10, ♂	Habitat.
<i>tripunctata</i> , Martin.....	♂ 59 ♀ 63	♂ 46 ♀ 48	♂ 36 ♀ 37	2·8	straight green bands	yellowish-green	waved 4·5	triangular 2	leaf-like 4·5	end of 9	normal	South-East.
<i>weiskei</i> , Förster	♂ 68 ♀ 63	♂ 54 ♀ 50	♂ 45 ♀ 48	2·5	bluish-green bands	yellowish	nearly straight 2·7	triangular 2	.....	.....	normal	N. Queensland.
<i>forcipata</i> , Tillyard (= <i>severini</i> , Förster)	♂ 66 ♀ 64	♂ 51 ♀ 49	♂ 44 ♀ 46	♂ 2·3 ♀ 3	straight green bands	dark green	forcipate 2·5	narrow truncate 1·7	straight 0·7	nearly to end of 10	normal	N. Queensland.
{ <i>unicornis</i> , Selys	♂ 64 ♀ 60	♂ 48 ♀ 46	♂ 44 ♀ 48	} 2·4	straight green bands	pale green	waved 2	truncate 1·2	straight 1·2	large, to end of 10	with a pyramidal tubercle	East (Victoria to South Queensland).
{ <i>unicornis pulchra</i> , Tillyard	♂ 61 ♀ 56	♂ 46 ♀ 40	♂ 38 ♀ 38		straight green bands	yellow	sub-forcipate 2	bifid 1·2	straight 1·4	end of 9	normal	Victoria, West Australia (?), Mount Kosciuszko.
<i>inermis</i> , Martin	♂ 64 ♀ 61	♂ 49 ♀ 44	♂ 42 ♀ 42	3	curved yellow lines and straighter bands	yellow	sub-forcipate 2	truncate 1·2	straight 1	just beyond end of 9	normal	Tasmania and Eastern Australia.
<i>longissima</i> , Martin	♂ 75 ♀ 64	♂ 58 ♀ 47	♂ 44 ♀ 44	3·7	curved blue-green bands	blue-green	waved 3·5	triangular 1·5	straight 1	end of 9	bluntly tubercled	Tasmania and South-East.
{ <i>parvistigma</i> , Selys	♂ 61 ♀ 59	♂ 46 ♀ 44	♂ 38 ♀ 40	2	whitish spots, no bands	cream or pale brown	waved 4	triangular 1·8	.....	.....	do., wider	Mount Kosciuszko.
{ <i>parvistigma flavomaculata</i> , [n. subsp.]	♂ 61	♂ 47	♂ 37·5	2	yellow spots and streaks	yellow	waved 3·7	sub-triangular, slightly truncate 1·5	.....	.....	.....	.....
<i>multipunctata</i> , Martin	♂ 63 ♀ 60	♂ 48 ♀ 45	♂ 41 ♀ 46	♂ 2·8 ♀ 3	curved grey-blue lines	cream or grey-blue	waved 3·5	truncate 1·2	straight 0·6	just beyond end of 9	sharply tubercled	East (Victoria to South Queensland).
<i>atrata</i> , Martin	♂ 72 ♀ 71	♂ 54 ♀ 52	♂ 45 ♀ 47	♂ 3·3 ♀ 4	dark slaty mottling	slate-grey, fading to brown	forcipate 3	truncate 1·2	straight 1	end of 9	strongly tubercled	South-East.
<i>anacontha</i> , Tillyard (= <i>aspersa</i> , Martin)	♂ 65 ♀ 61	♂ 50 ♀ 45	♂ 41 ♀ 44	♂ 3·5 ♀ 4	pale brown spots	pale brown	waved 4	narrow truncate 1·8	straight 1	somewhat beyond end of 9	normal	South-West.
<i>victoria</i> , Martin	♂ 63 ♀ 59	♂ 48 ♀ 44	♂ 37 ♀ 41	4	grey, with black bands	yellowish, clouded with black	waved 2	blunt triangular 1	short	?	normal	South-East.
<i>tasmanica</i> , n. sp.	♂ 68	♂ 50	♂ 41	2·5	mottled olive-grey	pale brown	straight 4	broad, bifid 1·5	.....	.....	very strongly tubercled	Tasmania.

depressed and converging, apical halves nearly horizontal, flattish, hairy, with well-rounded tips. Inferior appendage 1.8 mm., narrow-subtriangular, much upcurved, as in type.

Habitat. Mt. Kosciusko, N.S.W., at 5000-feet level. Taken by Dr. A. J. Turner, Jan. 23rd, 1914.

Type: Coll. Tillyard.

This very striking and beautiful subspecies is very different from the type-form in appearance, owing to the yellow colouring and greater size of its markings. It is of interest in showing the transition of a species possessing the coloration of Group II. (see above) back to that of Group I. on taking possession of an alpine habitat, where tall trees and dense forest are not present. The effect of living more in the open is seen at once by the development of the brighter coloration, while it is curious also to note the tendency shown towards a shortening of the superior appendages towards the form seen in *A. unicornis* and other species.

This is the first record of *A. parvistigma* from the Australian Alps.

AUSTROÆSCHNA TASMANICA, n. sp.

♂ unique. *Total length* 68, *abdomen* 50, *fore-wing* 42, *hind-wing* 41 mm.

Wings.—*Costa* brown, rest of *neuration* black, strong. *Submedian spaces* with 2, *hypertrigonals* with 2–3 cross-veins. *Triangle* of fore-wing twice crossed, that of hind-wing only once crossed, slightly shorter and broader. *Membranule*: fore small, 1 mm., greyish; hind 2 mm., greyish. *Pterostigma* 2.5 mm., black, strongly braced. *Nodal Indicator* $\left\{ \begin{array}{l} 18-19, 16-19 \\ 13, 17-18 \end{array} \right.$

Head.—*Occipital triangle* raised, black, hairy. *Vertical tubercle* black, hairy; central *ocellus* transparent yellowish, larger than the other two. *Front* hairy, pale straw-colour above, with a transverse median triangular brown mark connected to the ridge by its apex; rest of front shiny brown. *Post-clypeus* straw-colour, bordered irregularly with dark brown; *anteclypeus* dark brown. *Labrum* black, with two small, triangular, yellowish-brown spots close together at base; *genæ* with a round yellowish-brown spot; *labium* pale brownish, shaded and edged with dark brown.

Thorax.—*Prothorax* hairy, dark brown. *Meso-* and *metathorax* with grey hairs in front and around coxæ; glaucous brown, mottled with olive-grey as follows:—a faint and fine dorsal line on each side of dorsal ridge, curving outwards in front; dorsal ridge black, rising to an obtuse spine; each line ends in front in a small round spot, close to and behind which is a large elongate-oval humeral spot; on each side a small spot just in front of interalar ridge. On the sides considerable mottling, formed by about eight very irregular spots and marks of various sizes. A small but conspicuous white spot on the costal base of each wing. *Notum* black, *scuta* and *scutella* greyish. *Legs* black, with half of *profemora* and about two-thirds of middle and hind femora bright russet.

Abdomen.—1-2 much swollen, 3 much pinched near base, rest gradually widening to 10, which is 3·5 mm. wide. 1-2 hairy, brown with irregular black markings; 3-8 with transverse black carina, a pair of oval dorsal spots close together, and crossed by the carina; also, low down on each side, a larger oval mark crossed by the carina, and, on each side, a flat apical mark: all markings pale brown in the dead insect. 9, 3 mm. long, pale brown, with a black dorsal arrowhead-mark projecting from base to middle, and on each side a large basal black blotch. 10 black, rounded above, with a very large dorsal nodding tubercle; a broad pale brown apical band passes under the base of the tubercle.

Appendages.—*Superior* wide apart, 4 mm., black, hairy, bases narrowed, then slightly widening and curving inwards to tips, which are bluntly pointed outwards and about 1·5 mm. apart. *Inferior* very broad and short, 1·5 mm. long by 2 mm. wide, base slightly narrowed, end strongly bifid, black (Plate 9. figs. 11-12).

Type: ♂ unique, Hobart Museum (Hobart, February 1892).

This peculiar species, which Mr. Robert Hall, Curator of the Hobart Museum, kindly sent me for study, is without doubt very distinct from all other known species of the genus in possessing its remarkable bifid inferior appendage, and in the huge tubercle or spine on segment 10. It appears to be most closely allied to *A. atrata*, Martin.

AUSTROÆSCHNA INERMIS, Martin.

♀ unique. Total length 61, abdomen 44, fore-wing 43, hind-wing 42 mm.

Wings.—*Neuration* strong, black, except *costa* which is pale yellowish. Thickened antenodals on the first, and the third or fourth. *Nodal Indicator* [18-20, 14-15] [12-13, 15]. *Pterostigma* 3 mm., yellowish brown. *Membranule* whitish, fore 1 mm., hind 2·5 mm. *Triangles* 3-celled. *Anal loop* very small, 5-6-celled.

Head.—*Eyes* moderately large, meeting for 1·7 mm.; postocular triangle yellow; vertical tubercle and base of front dark brown; *front* yellow above, with a large brown T-mark, the cross-piece of which spreads downwards over the vertical portion as far as the *postclypeus*; the latter brown with a transverse yellow band next front; *ante-clypeus* dark brown; *labrum* dark brown with a pair of small yellow central spots separated by a brown line; *genæ* yellow; *labium* dark brown.

Thorax.—Large, with strong dorsal ridge, on either side of which lies a small curved yellowish band, thin and indistinct. Ground-colour rich chocolate-brown; sides with broad and fairly straight humeral and lateral bands, and a sublateral yellowish line; underside brown with grey hairs. *Legs* long, strong, black, most of femora dark reddish brown.

Abdomen.—1-2 much swollen, 3-10 cylindrical. Colour dark brown, marked as follows:—1, paler dorsally; 2 with four pointed yellow marks

arranged in the form of a cross, but not meeting centrally. 3-6 with two basal lateral spots, two central dorsal spots separated by mid-dorsal line, also indistinct sublateral markings, especially apically on 3-9; all these markings yellow. 7 with the central spots advanced to one-third from base, and a pair of short transverse apical lines. 8-9 with indistinct basal lateral marks, and a large dorsal apical yellow spot broadening out along suture. 10 very short, brown. *Ovipositor* reaching to end of 9. *Dentigerous plate* of 10 with six strong teeth. *Appendages* 1.4 mm., bluntly pointed, black.

Habitat. Australian Alps, 3000-5000 feet. Very rare. Jan. to March.

Types: ♂, Coll. Martin (Alexandra, Vic.). ♀ (unique), Coll. Tillyard (Mt. Kosciusko, N.S.W., at 5000-feet level, taken by Dr. A. J. Turner, Jan. 23rd, 1914).

Three males taken at the same time as the type-female, by Dr. Turner, agree very closely with R. Martin's description of the type-male. All four specimens are rather immature. The locality "O. Australie" given by Martin is surely an error.

Out of the twelve species of the genus *Austroaeschna* the larvæ of six are known to me. But I have only been able to study fully the life-histories of two of these, viz. *A. longissima* and *A. multipunctata*, these being the only two species occurring at all frequently within a hundred miles of Sydney.

AUSTROÆSCHNA LONGISSIMA, *Martin*.

This very graceful and beautiful species appears late in December and remains on the wing until April or May. It flies usually between 2 and 6 P.M., keeping very low and dashing swiftly up and down small mountain-creeks. It is very difficult to capture. The females, as is usual with all the entogenic Australian *Æschninae*, oviposit by themselves. They select an old half-rotten piece of wood or twig dipping into the water; and, settling on it with wings expanded, go about the process of oviposition very deliberately and slowly. I have watched them sometimes remaining in the same place for fifteen to twenty minutes, evidently experiencing some difficulty in rasping open the somewhat hard tissues of the wood in which their eggs are placed. The eggs are of the usual elongate-oval form (Plate 9. fig. 23) and measure 1.3 mm.; colour very pale straw. The young larva probably hatches out in the autumn, but remains very small throughout the winter, when food is practically unobtainable on the mountain-creeks. Specimens dredged in September are usually less than half-grown, quite black, hard, and spiny. They are very active, and if held in the closed hand can almost force their way out like a beetle.

Several specimens kept in my aquaria provided some interesting observations. They rest, when young, either on twigs or the stiff stems of water-plants, and seem to be continually on the watch, dodging round to the opposite side whenever I approached. They have a voracious appetite, and

much prefer fairly large articles of diet, *e. g.* very young *Æschnine* larvæ, and *Agrionid* larvæ of all sizes. These they stalk in a very deliberate manner, and very seldom fail to catch them. On the other hand, though they willingly eat mosquito larvæ, they do not find them easy to catch. I once saw one snapped at three or four times in succession without effect. Comparing this with the very effective stroke of the much shorter cup-like labium of forms like *Synthemis*, I think it is fair to conclude that the *Æschnine* labium is particularly suitable to the capture of fairly large prey, while the narrowness of its lobes, the length of its end-hooks, and the absence of setæ, all combine to make it a much less effective weapon for catching small prey than is the *Libelluline* labium.

The larvæ (two) were apparently full-fed just before Christmas, but remained dormant for a fortnight. For several days before emergence they crawled partly out of the water in the morning. One morning I found both out of the water on twigs, but on my approach they dived back again. The next day I found one of them dead and much swollen up; the other had crawled up the mosquito-netting and emerged. They were both females.

The newly emerged insect is semitransparent brown, with pale, almost colourless, spots. In a few days it becomes dark brown with pale yellowish spots. When quite mature the colour is almost black, the markings being a lovely blue-green, very evanescent after death. No other member of the genus has spots of this colour.

All the larvæ and exuvæ in my collection (five) are females. It is worthy of remark that, amongst Odonata, the subfamily *Æschninae* alone yields to the collector more females than males, both in larvæ and imagines.

Larva (♀).—Total length 36 mm., greatest breadth 7.5 mm. across eyes. Head.—5 mm.; postocular lobes prominent, 6.2 mm. across, subangular, carrying irregular tubercular swellings which cause the outer border to appear distinctly crenate. Labium.—Mentum 6×4.5 mm., reaching just to mesocoxæ, slightly narrowed basally (3 mm.) (Plate 6. fig. 5). Median lobe slightly projecting, slightly bilobed, carrying a row of stiff short hairs and a pair of short stout black tubercles (Plate 5. fig. 4). Lateral lobes of medium breadth, truncate distally, outer apical angle slightly rounded, the inner one toothed; inner border distinctly crenulate; movable hook strong, sharp, 1.3 mm. Thorax.—Prothorax 2×5.7 mm., with large bluntish dorso-lateral and two pairs of strong sharp sublateral spines close together. Meso- and metathorax strongly built, with two pairs of distinct lateral spines; wing-cases 8 mm. Legs strongly built, black, much spotted with pale brown. Abdomen.—Elongate-oval, well-rounded above, flattish below. No dorsal spines. Four pairs of lateral spines, those of 6 medium, 7–9 large. Appendages.—Superior 3.6, inferiors 3.9 mm., all strongly triquetral, very sharply pointed, somewhat hairy, tips bent inwards (Plate 7. figs. 5, 17). Involucres of female imaginal appendages, thin sharp spines, 1.5 mm.

Ovipositor reaching to middle of 10 (Plate 6. fig. 11). Colour.—Black, with rich mottling of paler brown markings; usually, conspicuous oval dorsal spots on 8–9, sometimes a smaller one on 7.

Larval Type: ♀, Coll. Tillyard. National Park, N.S.W.; emerged January 6th, 1905.

Habitat. This beautiful and graceful species is nowhere common, but is very widely distributed throughout Eastern Australia and Northern Tasmania. I have it from Mount Lofty Ranges, near Adelaide; Cataract Gorge, Launceston, Tas.; Alexandra, Vic.; Hill Top, Heathcote, National Park, Glenbrook, and Medlow Bath (3400 feet), N.S.W.; Guy Fawkes (4000–5000 feet), N.S.W.; Herberton (3000 feet), N. Queensland. The Herberton specimens, taken by Mr. F. P. Dodd, differ somewhat from the type, having shorter bodies and appendages, and might merit the rank of subspecies, though I do not propose to name them until I obtain more material.

Types: ♂ ♀, Coll. Martin; Victoria (probably Alexandra).

AUSTROÆSCHNA MULTIPUNCTATA, *Martin*. (Plate 4. fig. 6.)

This is undoubtedly the commonest species of the genus on the Blue Mountains, N.S.W., and also in Victoria. I have kept a number of the larvæ in my aquaria, and succeeded in breeding out several. The general account of the life-history given for *A. longissima* holds good also for this species, but with the following important differences:—

The perfect insect is the first of the genus to appear, my earliest record being November 28th (Dorrigo), but they are seldom seen until the second half of December. They remain on the wing until April. The larvæ are very different in appearance from those of *A. longissima*, being of a dirty-brown colour. Instead of living on submerged sticks, as *A. longissima* does, they hide in accumulated trash in the deep pools, or, more frequently, cling to the matted tangle of projecting roots and weeds that fringe the steep sides of the pools. In such situations they are not uncommon. When dredged they are usually slightly covered with sand or mud, especially on the appendages, which are very hairy. They are rather inactive, and usually feign death when handled. Their spines are small and harmless. The female oviposits in twigs or matted roots along the sides of deep pools in the mountain-creeks.

Larva.—*Total length* 37 mm., *greatest breadth* 7.5 mm. across eyes. *Head*.—5 mm., ocelli very prominent; *postocular lobes* roughened, regularly rounded. *Labium*.—*Mentum* 7.5 × 4 mm., reaching to between meso- and metacoxæ, where it narrows to 2 mm. (Plate 6. fig. 6). *Median lobe* somewhat projecting, bilobed, with a row of stiff short hairs and two small black tubercles. *Lateral lobes* narrowed, truncate, outer apical angle well rounded, inner one strongly toothed; inner border distinctly crenulated, movable hook 1.4 mm., sharp (Plate 5. fig. 5). *Thorax*.—*Prothorax* 1.8 × 5.5 mm., with

blunt dorso-lateral spines and two pairs of small sublateral spines close together. *Meso-* and *metathorax* without spines; *wing-cases* 8 mm. *Legs* of medium build, dark brown blotched with pale brown. *Abdomen* shaped as in *A. longissima*, with no dorsal spines; *lateral spines* on 6-9, small to medium (sometimes a tiny spine on 5). *Appendages*.—*Superior* 3.3 mm., triquetral, pointed, hairy; *inferiors* somewhat broader, a little more pointed, same length, hairy (Plate 7. figs. 6, 18); the three together form a closed pyramid much less sharp than the spines of *A. longissima*. *Involucres*: ♂ *superiors* 1 mm., sharp; *inferior* 0.8 mm., bluntly triangular, broad; ♀ sharp, 0.5 mm. *Ovipositor* 3 mm., reaching a little beyond end of 9 (occasionally to middle of 10) (Plate 6. fig. 12). *Colour*.—Dark brown, with very few markings except a row of more or less distinct pale dorsal spots on 3-10, those of 7-10 broad and conspicuous.

Larval Types: ♂ ♀, Coll. Tillyard. Medlow Bath, Blue Mountains, N.S.W. (♂ bred Dec. 26th, 1909).

Habitat. This rather sombre-coloured dragonfly occurs abundantly throughout the mountainous parts of Eastern Victoria and New South Wales; in South Queensland it is rare, occurring sparingly on Mount Tambourine.

The colour-scheme of grey-blue or creamy spots on a black ground is eminently suited to the habits of the insect, which is very fond of resting on the trunks of trees. A peculiarity of this and allied insects of the same colour-group is the bright russet colour of the legs, for which I am not able to offer any explanation, as they are quite the most conspicuous part of the insect. I can only suggest that the legs, being nearly hidden in the position of rest, have not been acted on in the formation of the protective colour-scheme from an originally much higher "hylochrome" coloration. This explanation is supported by the fact that in the closely allied *A. parvistigma*, an insect which, both in its coloration and its very short pterostigma, has departed even further from the original generic type, only the femora are bright russet, the tibiæ being almost black, with only a touch of russet (usually in the females), and the tarsi quite black. In the position of rest the femora are quite hidden, while the tibiæ and tarsi project beyond the body.

Types: ♂ Coll. Martin, ♀ Coll. Tillyard (Alexandra, Vic.).

AUSTROÆSCHNA PARVISTIGMA, *Selys*.

Two exuviae of this species were taken by me, a male at Launceston and a female at St. Patrick's River, in December 1908. Unfortunately I did not at the time consider *A. multipunctata*, Martin, as distinct from this species, and the specimens were not taken care of—at any rate, they are no longer in my collection. From my notes I find that the larva is very similar in general appearance to that of *A. multipunctata*, but differs as follows:—*Total length* only 35 mm., *breadth* of abdomen 6.5 mm. *Ovipositor* not so

long as in *A. multipunctata*, reaching just to end of 9. *Involucre* of male inferior appendage more pointed. *Labium* and *appendages* apparently very similar to those of *A. multipunctata*.

Habitat. Mountains of South Australia and Tasmania, especially the west and north. I have no definite records for Victoria or southern N.S.W.; all my captures at Alexandra and Mount Kosciusko were *A. multipunctata*. It occurs, however, *in company with the latter*, at Guy Fawkes, N.S.W. (4000–5000 feet), and I was very pleased to add a single male taken at Hill Top, N.S.W., also in company with *A. multipunctata*, to my records on March 30th last. Now that I have long series of both species, all doubt as to their distinctness is removed. The chief differences have been pointed out by me in a former paper*. Their occurrence together in the same localities places the matter beyond the region of doubt, as they can no longer be regarded as distinct geographical races.

Types: ♂ Coll. Selys, ♀ Coll. Martin. (Localities not stated.)

AUSTROÆSCHNA UNICORNIS, *Selys*.

Only two exuviae of this very beautiful species have been found. The first was found by me emerging on Jan. 13th, 1912, at Guy Fawkes (Ebor), N.S.W.; the second was taken by Mr. G. A. Waterhouse at Stanwell Park, N.S.W., Feb. 22nd, 1913. Both are females, and both belong to race *pulchra*, Tillyard. As this race was originally described by me from Lily Vale, near Stanwell Park, I have fixed Mr. Waterhouse's specimen as the larval type.

Larva (♀).—*Total length* 31 mm.; *greatest breadth* 7 mm. across abdomen at 7. *Head*.—Smallish, 4·8 × 6·5 mm.; *postocular lobes* not prominent, smooth, rounded; *front* projecting, narrow, 2 mm. *Labium*.—*Mentum* 7 × 3·5 mm., very long and narrow, reaching well up to mesocoxæ, where it is narrowed to 1·7 mm. (Plate 6. fig. 4). *Median lobe* very flat, slightly bilobed, carrying two small tubercles. *Lateral lobes* narrow; tip rounded, nodding; inner margin finely crenulate; movable hook thin, sharp, 1·2 mm. (Plate 5. fig. 3). *Thorax*.—*Prothorax* 1·5 × 4·5 mm., with one pair of blunt dorso-lateral and two pairs of sharper sublateral spines. *Meso- and metathorax* smooth, with slight indications of incipient spines; *wing-cases* 6·5 mm. *Legs* short, fairly strong, dark brown, much spotted with pale brown. *Abdomen* shaped as usual, with no dorsal spines; *lateral spines* on 5–9, those of 6 small, 7–9 medium; 5 with a tiny spine. *Appendages*.—*Superior* 2·9, *inferiors* 3 mm., shaped very much as in *A. multipunctata*, but less hairy; tips of inferiors sharper and slightly bent inwards (Plate 7. figs. 4, 16). *Involucres*, ♀, 0·4 mm., sharp. *Ovipositor* large, reaching well beyond end of 10, and curving up between inferior appendages (Plate 6. fig. 10). *Colour*.—Dark brown, mottled with paler brown;

* Proc. Linn. Soc. N.S.W. 1912, part iv.

large pale dorsal spots on 8-10 ; 4-6 with three small dorsal spots each, in a triangle.

Larval Type: ♀ Coll. Tillyard. (Stanwell Park, N.S.W.)

The second exuviae, also ♀, from Guy Fawkes, measures 35 mm. and is darker.

Habitat. The type-form is found in Victoria. The smaller and very beautiful race *pulchra* occurs rarely on the Blue Mountains and coastal spurs, N.S.W. ; it was described by me from specimens taken at Lily Vale, on the Illawarra Line. A fine series taken by me at Guy Fawkes, at 4000 feet, averages as large as the type-form, but possesses, in the male, an inferior appendage quite as strongly truncate as in race *pulchra*. The second ♀ exuviae belongs to this series. I have also taken two very handsome and darkly coloured males at Mount Tambourine, S. Queensland, whose coloration reminded one exactly of that of *A. forcipata*.

The female of this species uses its very long ovipositor for placing its eggs in the tissues of mosses and other small plants growing on damp rocks, usually a foot or more above the summer level of the water.

De Selys originally described this species from a unique female, locality simply "Australia." Martin added the description of the male from a Victorian specimen.

Types: ♂ Coll. Martin, ♀ Coll. Selys. Race *pulchra*, ♂ ♀ Coll. Tillyard.

AUSTROÆSCHNA ANACANTHA, *Tillyard*.

Austroeschna anacantha, Tillyard, Proc. Linn. Soc. N.S.W. xxxii. 1907, p. 732 ; Ris, Die Fauna S.-W. Australiens, 1910, p. 432.

Austroeschna aspersa, Martin, Æschnines, Coll. Selys, fasc. xix. p. 96.

The habits and appearance of this species have been already fully dealt with by me (see reference above). It is confined to the south-west corner of Australia, and is undoubtedly the western geminate representative of an original eastern form which later on gave rise to both *A. parvistigma* and *A. multipunctata*. Mr. G. F. Berthoud found it abundant at Waroona on Jan. 4th, 1912, and collected a fine series of larval exuviae, which he kindly sent me.

Larva.—*Total length* 33 mm. (average), *greatest breadth* 8 mm. across eyes. *Head*.—5 mm. ; *eyes* rather large ; *postocular lobes* not prominent, rounded, somewhat crenulate. *Labium*.—*Mentum* 5.5 × 4 mm., reaching to between pro- and mesocoxæ, where it narrows to 2.7 mm. (Plate 6. fig. 8). *Median lobe* slightly convex (with very slight median depression), carrying a row of short hairs and a pair of very small tubercles. *Lateral lobes* narrow, truncate, outer apical angle rounded, inner with very small tooth ; inner border distinctly crenulate ; movable hook 1.2 mm., sharp (Plate 5. fig. 6). *Thorax*.—*Prothorax* 1.7 × 4.7 mm., with one pair of blunt dorso-lateral and two pairs of sharp sublateral spines. *Meso-* and *metathorax* fairly smooth,

with flattish lateral tubercles; *wing-cases* 8·5 mm. *Legs* medium, dark brown with pale spots. *Abdomen*.—Of the usual shape; no dorsal spines; *lateral spines* on 6–9; small on 6, medium on 7–9. 10 quite 1·5 mm. long. *Appendages*.—*Superior* and *inferiors* of same length, 3·5 mm., somewhat hairy, shaped as in *A. multipunctata*. *Involucres*: ♂ *superiors* 1 mm., sharp; ♂ *inferior* 0·7 mm., broadly triangular, rather blunt; ♀ 0·2 mm. (Plate 7. figs. 7, 19). *Ovipositor* of ♀ medium, reaching to first third of 10 (Plate 9. fig. 4).

Larval Types: ♂ ♀, Coll. Tillyard. (Waroona, Jan. 4th, 1912.)

From the figures and description there can be no doubt that the unnamed “*Æschnine-larva C*” described by Dr. F. Ris on p. 446 of his “*Fauna S.-W. Australiens*” belongs to this species.

Imaginal Types: ♂ ♀, Coll. Tillyard. (Wilgarrup, W.A., Jan. 1907.)

AUSTROÆSCHNA ATRATA, *Martin*.

A single male of this fine species was found by me emerging at Guy Fawkes, N.S.W., on Dec. 22nd, 1911. The following is a description of the exuviae:—

Larva (♂).—*Total length* 37 mm., *greatest breadth* 8 mm. across eyes. *Head*.—6 mm.; *eyes* large; *postocular lobes* well rounded, very dark, with a pale crenulated outer patch. *Labium*.—*Mentum* 6 × 5·2 mm., reaching only just to mesocoxæ, where it narrows to 3·3 mm. (Plate 6. fig. 7). *Median lobe* very flatly bilobed, carrying a row of hairs, a pair of large tubercles and a pair of smaller tubercles, the latter being closer to the median depression. *Lateral lobes* of medium breadth, tips truncate; outer apical angle rounded, inner toothed; inner margin crenulated; movable hook 1·6 mm., sharp (Plate 5. fig. 13). *Thorax*.—*Prothorax* 2 × 5 mm., with very blunt dorso-lateral and two pairs of sharper sublateral spines. *Meso- and metathorax* strongly built, with very flat lateral spines; *wing-cases* 8·5 mm. *Legs* very large and strongly built, very dark, slightly spotted; hind femur 8 × 1·2 mm. *Abdomen*.—Of the usual shape, very rounded above; no dorsal spines; *lateral spines* on 5–9; very small on 5, medium on 6–9. *Appendages*.—*Superior* and *inferiors* 3 mm., somewhat hairy, strongly pointed, tips slightly incurved. *Involucres*: ♂ *superiors* 1·2 mm., pointed; ♂ *inferior* 0·7 mm., broad, bluntly rounded (Plate 7. figs. 8, 20).

Larval Type: ♂, Coll. Tillyard. Guy Fawkes (Ebor), N.S.W., Dec. 22nd, 1911.

Easily distinguished from all other known larvæ of the genus by its broad massive labium with two pairs of median mental tubercles and its exceedingly large legs.

Habitat. This somewhat rare species is confined to the mountains of Victoria and N.S.W. I have taken it at Alexandra, Vic.; on the Blue Mountains and at Guy Fawkes, N.S.W. Although the dead specimens

appear a dull black, it is worthy of note that mature males when freshly captured have a very delicate pale grey-blue pattern, unlike any other dragonfly known to me. The name "*atrata*" therefore is scarcely a fortunate one, especially as *A. anacantha* is, in point of fact, a very much blacker species when alive.

Genus 3. NOTOÆSCHNA*, n. g. (Plate 4. fig. 7.)

Characters as in *Austroæschna* (restricted), but with the following important differences:—

Front large, rounded and swollen, standing well up above level of eyes. *Wing-membrane* very strong, with thick border. *Neuration* very strong and open. In the series of antenodal cross-veins, the first and fourth in the fore-wing and the first and third in the hind-wing are complete and triangularly thickened, and the more distal of the two stands close up to (or even, in the hind-wing, *exactly at*) the level of the arculus; in *Austroæschna* the corresponding cross-veins are the first and fifth (with few exceptions), and this latter vein is further from the arculus. *Triangle* of hind-wing distinctly shorter than that of fore-wing, usually only two-celled in male. M_4 less waved than in *Austroæschna*, running practically in a single very flat curve for its whole length. *Sectors of arculus* arising separately at about its middle (in *Austroæschna* they arise closer and lower down). *Membranule* fairly large. *Legs* very large and strong, with large tarsal claws. *Female* with dentigerous plate under segment 10 obsolescent, but with a very remarkable strong spine at the dorsal end of 10, above and between the anal appendages. *Ovipositor* much reduced (Plate 9. figs. 13–14).

Larva remarkably spiny, with small dorsal hooks on 3–9, large lateral spines on 5–9, short spiny superior appendage and enormous spined inferior appendages. *Labium* with smooth, narrow, rounded inner lobe.

Type: *Austroæschna sagittata*, Martin.

This remarkable dragonfly stands out as by far the most highly specialized of our entogenic Australian *Æschnine*. It may be regarded in many respects as a cænogenetic offshoot from the main *Austroæschna*-line quite comparable to *Anax* in relation to the main *Æschna*-line, though the cænogenesis has not proceeded quite so far. In the specialization of its larva it far outruns any other *Æschnine* form known to me (except, perhaps, *Telephlebia*). As Martin has already very accurately described both sexes †, I will only add a few important points, and give a full description of the larva and a few notes on the life-history.

Imago.—The large *front* is dark brown to black all over except for a

* Greek *Nóros*, the South Wind. The prefixed *Noto*- and *Austro*- may conveniently be used to denote purely Australian genera. Before the "æ" of *-æschna* the "o" may be retained for euphony.

† Martin, *Æschnines*, Coll. Selys, fasc. xix. p. 236.

nearly straight green band running across from eye to eye in front of antennæ, and interrupted medially by a thick cross-bar which may be taken as the stem of a very indistinct and much swollen "T-mark." The colour-scheme of thorax and abdomen varies somewhat, and a very fine and long series taken by me at Guy Fawkes, N.S.W., is distinct enough to merit a varietal name. I therefore propose for it the name var. *geminata* defined by the following characters :—

Dorsal thoracic rays reduced to fine slightly curved green lines ; lateral bands broad, straight, yellow, without any sign of a third intervening band. Sagittate dorsal spots of abdomen much reduced, each being split into two geminate subtriangular halves separated by the black line of the dorsal ridge. Types : ♂ ♀, Coll. Tillyard.

The end-segments of the female are so remarkable as to deserve special study. There is a reduction in the size of the ovipositor to a length of only 2 mm., so that it projects out strongly under segment 9, but does not reach beyond it. The styli are short and black, projecting transversely, apparently only one-jointed, ending in a stiff bunch of black hairs. Segment 10 is somewhat lengthened, and shows underneath a rudiment of what was probably once a dentigerous plate. The very sharp spine developed at the dorso-apical end of 10 is well shown in Plate 9. fig. 13, and is most probably an organ used in oviposition in place of the dentigerous plate. [For end-segments of ♀, see Plate 9. figs. 13–14.]

In a steep gully at Guy Fawkes, cut out of basalt, down which rushed a mountain-torrent, I found, about the 4000-feet level, a small level tract where two streams met, and where a small bog was formed overgrown with tea-tree. At the end of December, 1911, on hot sunny days, *N. sagittata*, var. *geminata*, was abroad over this small bog in fair numbers. It flies gracefully at a good speed over the tops of the bushes and round the trees, only occasionally dropping to seize an insect. They were most difficult to catch until I conceived the idea of hiding behind a clump of tea-tree over which they careered in procession. By this means I netted about two dozen, mainly males, in the course of several visits, the rate of capture being about one every twenty minutes. Of the larvæ I found three only. I was fortunate enough, one day, to observe a pair flying high, *in cop.*, and shortly afterwards the female separated from the male and dived down to a part of the bog just in front of me. Creeping cautiously forward, I observed her fluttering low along the reedy edges of the boggy puddles. She half settled on a clump of reeds and dipped the tip of her abdomen into the water as if to oviposit. At that moment, when I hoped to observe her method of oviposition fully, she became alarmed and flew up straight towards me. Fortunately I netted her, and she almost immediately exuded a small cluster of large elongate-oval pale yellowish eggs. A few more single eggs followed, totalling in all over twenty—a far larger number than I have ever obtained

voluntarily from any other female *Æschnine*. The ova measure 1.2×0.4 mm., in shape elongate-oval, somewhat broader than usual in *Æschnine* (Plate 9. fig. 22). In spite of much careful waiting and watching, this was the only time that I ever saw this species ovipositing.

Putting all these facts together, it seems reasonable to suppose that this species has thrown over the ancient but laborious usage of its relatives, who oviposit in moderately hard tissues by means of their rasping-apparatus or dentigerous plate, and has adopted the method of simply boring into softer green tissues. I should like to be sure how this is done, but my own opinion is that the female bends her body round until she can ram her sharp spike into the tissue, makes the hole large enough, and then simply slips the egg into the hole. One can scarcely credit the much abbreviated terebra with any great powers of guidance, much less of boring.

The flight of this species is strong and long-sustained, very much like that of *Anax papuensis*. It is therefore interesting to note the great strength of the anal triangle of the male and the strong anal angle, both built on the exact plan of a typical *Austroeschna*, only "more so." Now, in *Anax*, such a structure could not have been developed, since its ancestors undoubtedly possessed the long and narrow anal triangle typical of *Æschna*, and fringed by a very long membranule. The wing-strengthening therefore took an opposite turn, ending in the complete abolition of the weak anal triangle and the formation of a strong rounded wing. Both final types give a fine result in flight-power. The strongly angulate wing seems to be superior for darting, the rounded wing for soaring and skimming. The two forms reach their maximum developments, the one in *Macromia*, the other in the *Libelluline*. The shifting of the arcus sectors upwards must also not be lost sight of as a factor for strength in both *Notoeschna* and *Anax*, while much of the sustained power of flight is due to the great strength of the wing-membrane and veins themselves.

Larva.—*Total length* 37.5 mm.; *greatest breadth* 8.5 across segment 6. *Head*.—5.7 mm.; *breadth across eyes* 7 mm.; *postocular lobes* well rounded, smooth. *Labium*.—*Mentum* 4.5×5 mm., broad and short, reaching back only to between procoxæ, where it is reduced to 3 mm. width (Plate 6. fig. 9). *Median lobe* projecting as a very obtuse triangle, without median depression, hairs, or tubercles. *Lateral lobes* narrow, apex well rounded, inner margin not crenulated, movable hook rather thick and short, 1.2 mm. (Plate 5. fig. 8). *Thorax*.—*Prothorax* 2.7×7 mm., with very blunt dorso-lateral and two pairs of sharp sublateral spines. *Meso- and metathorax* fairly smooth, no spines; *wing-cases* 8 mm. *Legs* very strong and large; *profemora* 6×1.8 mm., flattened, and carrying a strong dorso-basal spine; *2nd femora* 8×1.9 mm.; *hind femora* 10×1.9 mm., both without spines but much flattened; *tibiæ* of medium width, rather flattened; *tarsi* with large diverging hooked claws. *Abdomen*.—Of the usual shape, but carrying small nodding *dorsal spines*

or hooks on raised segmental ridges on 4-10, sides of 3-4 angulated, but not spined; *lateral spines* large on 5-9 (Plate 9. fig. 16). *Appendages*.—Very remarkable; *superior* 2 mm., small, very sharp, carrying above it in the male the rather blunt inferior imaginal involucre, in the female a sharper spine, the involucre of the dorso-apical imaginal spine of 10; *inferiors* very long, 5 mm., sharp, slightly incurved, and themselves armed with smaller spines and a row of stiff hairs; involucres of male superior appendages and of female appendages equally long and sharp, 2 mm. (Plate 7. figs. 9, 21). *Ovipositor* very small, only covering segment 9 (Plate 9. fig. 2).

Larval Types: ♂ ♀, Coll. Tillyard. (Guy Fawkes, N.S.W., Jan. 13th and 14th, 1912.)

Habitat. This insect is of somewhat restricted range on the mountains of Eastern Victoria and N.S.W. I have taken it near Alexandra, Vic. (Rubicon Falls), on the Snowy River at Jindabyne, on the Blue Mountains (rare), and at Guy Fawkes (var. *geminata*).

Types: ♂ ♀, Coll. Martin (♂ Victoria, ♀ N.S.W.). Var. *geminata*, ♂ ♀, Coll. Tillyard.

III. ECTOGENIC GROUP.

Tribe *ÆSCHNINI*.

A. *ÆSCHNA* SERIES.

M_2 arching strongly up under pterostigma. *Rs* either not clearly forked at all, or unsymmetrically forked close up to or under the level of the pterostigma. *Rspl* curved concavely to the lower branch of the fork, so as to enclose several rows of cells between; *Mspl* similarly concave to M_4 . Hind-wing of male angulated, about the same width near base as at nodus; the anal triangle long and narrow. Membranule large. Anal appendages not exceptionally long. Females with dentigerous plate under segment 10 either vestigial or absent. Auricles present in male.

Larva with superior appendage bifid at tip, slightly shorter than the sharply pointed inferiors. No setæ on lateral lobes of labium. No papillæ on rectal gills.

Only one genus is represented in Australia:—

Genus 1. *ÆSCHNA*, *Fabr.*

Characters as above, with these additions:—Basilar space free; pterostigma braced; radial sector forked unsymmetrically, sometimes scarcely forked at all (in the Australian species); triangles fairly elongate, typically 5-celled; subcosta not prolonged beyond nodus.

Type: *Æ. juncea* (Linn.) Burm.

Note on the Name *Æschna*.—A great deal has already been written regarding Fabricius's now famous word "*Æshna*," which all subsequent

authors for well over a century tacitly altered to *Æschna*, thereby entering a very solid protest against the acceptance of a word that is not of Greek form. It seems quite certain that Fabricius never really wrote the word "*Æshna*" (since in his time classical tradition was far stronger than at present), but that the word as it was published was an error of the pen or of the printer. As the manuscript is lost, we shall never know for certain what he wrote. But it is of interest to note that, as "s" cannot precede "h" in Greek, the "s" was almost certainly a misprint for another letter, and that letter was almost certainly the "c" of the Greek χ or "ch." If, besides this, the "n" were a misprint for "m," we obtain the very beautiful and suggestive name *Æchma* (derived from Greek $\alpha\iota\chi\mu\eta$ = Latin *cuspis*, a spear-point or spear). This word very likely gave the clue to Leach in the selection of *Cordulia* and *Gomphus* later on, since all three describe accurately the shape of the abdomen—"spear-," "club-," or "wedge-shaped." This attempt at solving an almost hopeless puzzle is only offered on sentimental grounds, for no alteration can now be made, and this strikingly beautiful group of insects must be for ever saddled with an ugly and meaningless name. *Æschna* is bad enough, but it is Greek in form. "*Æshna*" is a complete barbarism, and therefore cannot be accepted.

ÆSCHNA BREVISTYLA, Rambur. (Fig. 3, p. 5.)

Rambur, Hist. Nat. Névropt. 1842, p. 205.

This is a somewhat variable species, so that, if two specimens were taken at haphazard and compared, one might be tempted to consider that there were two subspecific forms. But after collecting a very large number of specimens from all parts of Australia, and examining series from both the north and south islands of New Zealand and from the Kermadecs, I have come to the conclusion that all variations are purely individual. At first sight New Zealand specimens appear somewhat smaller and darker, with denser reticulation and shorter abdomen than in Australian specimens. On the average, this is no doubt the case; yet I have quite a number of Australian specimens almost indistinguishable from New Zealand ones. So far I have never yet seen a male specimen with only two cells in the anal triangle, though Martin says that specimens from New Zealand have only two as against the typical three-celled anal triangle. All New Zealand specimens seen by me have three cells. The two-celled variety can therefore be only very local or seasonal; it may also possibly occur in Australia.

The most variable feature is the dorsal thoracic colour-scheme, of which one may recognize three varieties:—

A. *Typical form*, with a pair of straight, narrow, dorsal green bands.

B. Var. *lineata*, with the dorsal bands reduced to lines.

C. Var. *oblita*, with no markings at all on the dorsal part of the thorax.

Generally speaking, the largest specimens are typical, the smallest usually

var. *oblita*; also many more males of var. *oblita* occur than females (the latter are generally larger, too, than the males). All the males I have seen from New Zealand are of var. *oblita*, while the females are either var. *oblita* or var. *lineata*. But both forms occur frequently in Australia also. In one afternoon I have caught in a circumscribed area of less than a quarter of a mile, along a small creek, all three varieties in both sexes. A pair taken *in cop.* in Western Australia proved to be var. *oblita* ♀ paired with a very large and typical ♂! Hence it will be seen that no attempt can be made to subdivide the species into regional forms.

The whole colour-scheme varies very greatly. In the males the prevailing colour is pale green on a dark brown ground; but in less mature specimens every shade of cream, straw, yellow, pale blue, and blue-green, not to mention dirty pale yellows and browns, may play a part—even to the extent of all being represented on different parts of the same specimen. In the female the colours are rarely as bright, and many of the abdominal spots are often dirty brown or grey; yet I have taken some females very beautifully marked with green.

It is an interesting fact to notice that, when flying, this insect appears to be broadly striped from end to end slantwise with a zebra-like pattern, while all the different species of *Austroeschna*, some of which are even more richly spotted with green, appear dark brown or black when flying.

Larva.—*Total length* 39 mm.; *greatest breadth* 8·5 mm. across eyes. *Head*.—*Eyes* large and prominent; postocular lobes rounded; whole upper surface irregularly roughened or shagreened. *Labium*.—*Mentum* 7·5 × 5 mm., reaching to between meso- and metacoxæ, where it narrows to 2·5 mm. (Plate 5. fig. 15). *Median lobe* slightly projecting, slightly bilobed, carrying a row of short hairs. *Lateral lobes* fairly broad and long, apex squarely truncate, with outer angle very little rounded and inner angle strongly toothed; inner margin with only the slightest trace of fine crenulations; movable hook strong, sharp, curved, 1·9 mm. (Plate 5. fig. 10). *Thorax*.—*Prothorax* rather small, 1·8 × 5 mm., narrowing laterally to a vertical ridge about 1 mm. wide with scarcely a vestige of any lateral spines. *Meso-* and *metathorax* strongly built, regular, smooth, except for slight shagreening; *wing-cases* 8 mm., those of hind-wings 2·8 mm. wide. *Legs* medium, smooth, femora not much flattened. *Abdomen*.—Smooth, well rounded above, fairly flat beneath, widest at 7, then tapering considerably to 10. No dorsal spines or hooks; *lateral hooks* on 7–9, small to medium. *Appendages*.—*Superior* 3·8, strongly bifid at tip; *inferiors* 4·2 mm., very sharp. *Involucres*: male superiors 1·2 mm., pointed, inferior 1 mm., broad, subtriangular; female 1 mm., sharply pointed (Plate 7. figs. 10, 23). *Ovipositor* very small, covering only two-thirds of 9; involucres of styli very distinct (not noticeable in the entogenic Australian genera) (Plate 9. fig. 6). *Colour*.—Rich dark brown, with very little pattern; usually a pale dorsal line bordered on each

side by a longitudinal row of blackish segmental patches most evident on the basal half of each segment; also more or less conspicuous lateral dots and bands, segmentally arranged.

Larval Types: ♂ ♀, Coll. Tillyard (♂, Sydney, bred Oct. 9th, 1907; ♀, Heathcote, N.S.W., bred Nov. 9th, 1908).

This larva is easily distinguished from all the preceding ones by the form of its superior appendage; also by its broader and more strongly toothed lateral labial lobe. In general form it much resembles the nymph of *Anax papuensis*, Burm., but is of smaller size and very different coloration.

Life-History.—This common species is out on the wing by the end of September, and a continuous succession of individuals appears until well into November. Pairing takes place up to the end of the year; after that time one seldom meets with males of this species at all. The female usually oviposits by herself, inserting her eggs one by one into the tissues of reed-stems or half-rotted twigs or roots projecting from the creek-banks. On sluggish streams oviposition may take place anywhere; but on swiftly running creeks this species is careful to select only the larger and more stagnant pools. Dirty, muddy, slow-moving creeks and rivers are its favourite haunts. The eggs are of the usual *Æschnine* form, narrow, elongate-oval, 1.4 mm. long by about 0.3 mm. wide, pale cream or straw-colour. Females captured while ovipositing never exude more than two or three eggs at the most. The best plan to obtain the eggs is to watch the female ovipositing and then to gather the reed-stem and slit it open, when the eggs will be found embedded slantwise in the tissues.

The young larva is a voracious feeder and very cannibalistic. It grows rapidly, and I have very little doubt that the normal time for reaching complete maturity is only one year in this species. When dredging in September only full- or nearly full-grown larvæ can be obtained. The best places to find these larvæ are along the steep banks of pools in slow-running creeks, where they either hide in projecting masses of water-weed or, more frequently, cling to the débris of the sides of the creek. This larva is, as far as I know, *never* found in water-holes or any quite stagnant water; but it does not object to foulness and mud, provided there is the slightest current running. Hence it is never found in the favourite haunts of the nymph of *Anax papuensis*, though occasionally the latter may occur in the same pools of a very slow creek. In such cases the larger *Anax* nymph inhabits the reed-stems, especially towards the more central parts of the pool, while the *Æschna* nymph keeps to the sides.

In the aquaria these nymphs have to be kept apart from other species. Any of the entogenic Australian *Æschnine* larvæ speedily fall a prey to it, not only because of its voracity, but because it is always in a more advanced state of development, being a good two months ahead of any of these species. Libellulid larvæ are attacked and bitten into pieces, but not much of them

is eaten; Agrionid larvæ are greedily consumed. When all else fails, cannibalism becomes rampant, and the final result attained is that only two or three nymphs survive, becoming rapidly full-fed at the expense of all the rest. Each survivor jealously guards its own corner of the aquarium, and woe to the one that is taken unawares.

I have not been able to determine the total number of ecdyses in this or any other dragonfly larva. Larvæ captured at about 10–12 mm. length undergo either four or five ecdyses before becoming full-fed. The total number would appear therefore to be ten or more, for at 12 mm. the larva has reached a stage in which the wing-cases can be seen as small rudiments. The full-fed nymph becomes more or less dormant for a period varying from two days to a week. The colder the weather the longer does this “dormant” period last. The nymph of *Æ. brevistyla* nearly always makes “trial” excursions out of the water for a few days: at first resting for an hour or two in the morning with only its head projecting; then, with half its body, or more, out of the water. Finally, it climbs up a stick or reed-stem and emerges in the usual fairly rapid manner, the abdomen attaining a fair length before the wings expand, but afterwards reaching its full length and slender shape rather slowly. The emergence nearly always takes place in the early morning; but, during thundery weather, large numbers may be seen to emerge together, even late in the afternoon, before or even during the storm.

Habitat. This species is very common throughout the temperate portion of Australia, ranging from Western Australia across to South Queensland, and being also quite common in Tasmania. In Northern Queensland it is exceedingly rare, and I doubt whether it extends to Cape York. It is common in New Zealand and the Kermadecs. This distribution is of considerable interest, showing as it does a distinct southern origin for the species. As the New Zealand form, on the average, appears to be somewhat more reduced than the Australian, I am inclined to regard this species as a single remnant in Australia of a once more plentiful Antarctic *Æschna*-group of species, of which *Æ. diffinis*, Rambur, may possibly be another representative in Patagonia, Chili, and Argentina. As nearly half the known species of the genus *Æschna* occur in the Neotropical Region, it seems possible that our one Australian species is truly an offshoot from that great group, having travelled, with others since extinct, southwards to a temperate Antarctica, from which it was at last driven out to take refuge in Tasmania and New Zealand. Also it must have spread from Tasmania to the mainland before the separation of the two; for, in spite of its size and powers of flight, it has no migratory instinct, and rarely travels more than a few hundred yards from its breeding-places. We have also the remarkable fact to consider that *Anax papuensis*, a larger and stronger flier than *Æ. brevistyla*, and belonging to a group with more migratory tendencies, which has worked into Australia

from the north, has not succeeded in crossing over to Tasmania, though it is exceedingly common along the Victorian coast-line. This evidence seems to point very conclusively to the fact that *Æschna* is a much more archaic genus than *Anax*, the former being Tertiary and the latter post-Tertiary as regards the time of its appearance on this continent.

Types: ♂ ♀, Coll. Selys. (Australia.)

B. ANAX SERIES.

M_2 arching strongly and suddenly upwards at about the level of the end of the pterostigma. *Rs* not clearly forked, but giving off posteriorly a set of nearly parallel slanting branches, so that the cells between it and *Rspl* lie in regular slanting sets; the last of these branches is more oblique than the others, and represents the lower branch of the "fork." Sectors of arculus arising close to its upper end. Pterostigma long, braced. *Hind-wing* widest near base, with anal border of male *rounded*, the membranule very large and elongated. *No auricles* present in male. Female with dentigerous plate reduced to a very finely denticulate rounded prominence.

Larvæ with bifid superior appendage, very large head and eyes, no setæ on lateral lobes of labium. Papillæ developed on rectal gills.

Only one genus, *Anax*, is represented in this series. Three species occur in Australia.

Genus 1. ANAX, Leach.

Characters as given (see above). Type: *A. imperator*, Leach.

ANAX GUTTATUS (*Burm.*).

Æschna guttata, *Burm. Handb. Entom. ii.* (1839) p. 840.

This fine species is common in the Oriental Region. The first Australian record for it was made in 1905, when I discovered it on the Carrington Swamp, near Atherton, N. Queensland. Since then I have taken it at Townsville, Cairns, and Cooktown. In the latter locality it is quite common on all the swamps. I have also received it from Port Darwin (Mr. F. P. Dodd). All the specimens are of typical form, without any trace of a T-mark on the front. I do not know the larva.

ANAX GIBBOSULUS, *Rambur.*

Rambur, Hist. Nat. Névropt. 1842, p. 187.

This species is a new record for Australia. Mr. F. P. Dodd sent me a fine male and two females from Port Darwin, December 1908, and informed me that they were not uncommon there. To this species I am now also able to refer a single female taken by me at Atherton, January 1905, which I had placed temporarily with my series of *A. guttatus*.

A. gibbosulus is a larger and much more gracefully built species than

A. guttatus, the latter being thick-set, with shorter abdomen and appendages. The saffroning of the middle of the hind-wing is much more pronounced in *A. gibbosulus* than in *A. guttatus*, and the front has a distinct T-mark. In the description given by Martin ('Æschnines,' p. 24) no mention is made of some striking features of coloration, probably obliterated in the specimens under review by him. These are :—

Abdomen.—1, yellowish above, blue on sides. 2, basal quarter similar to 1, bordered basally and distally by nearly black transverse bands, of which the distal one projects dorsally into an angle which enlarges over the distal two-thirds of the segment to form a conspicuous black cross; all the rest of the segment bright blue, like porcelain in appearance. 3, dark brown, sides of basal half bright blue; two small green apical spots. 4–6 with pairs of large green basal and apical spots. 7–10 with two large green apical spots only. ♂ **Appendages.**—*Superior* 6·5 mm. (*A. guttatus* only 5·5) with narrow bases; broad leaf-like, ridged above, ending in a sharp outer spine, on the inner side of which the apical margin is distinctly hollowed out (in *A. guttatus* this margin curves round to the interior without any concavity). *Inferior* 2 mm., broad, truncate, very slightly bifid (less so than in *A. guttatus*). ♀ *appendages* leaf-like, 5 mm. (those of *A. guttatus* only 3 mm.). In both sexes of *A. gibbosulus* the abdomen is more pinched at 3 than in *A. guttatus*, and from thence on widens out much more gradually, ending up with 9–10 5 mm. wide (10 4 mm. in ♀); in *A. guttatus* the widening is more abrupt at the apical half of 3, and thence on is very gradual.

Measurements.—*Total length*, ♂ 92, ♀ 90; *abdomen*, ♂ 70, ♀ 67; *hind-wing*, ♂ 52, ♀ 55 mm. [Corresponding measurements for *A. guttatus* are :—♂ 84, 62, 53, ♀ 80, 58, 53.]

ANAX PAPUENSIS (Burm.) Brauer. (Plate 4. fig. 8.)

Æschna papuensis, Burm. Handb. Entom. 1839, p. 841.

Anax congener, Rambur, Hist. Nat. Névropt. 1842, p. 191.

Anax papuensis, Brauer, 1866 (Novara, p. 63); Karsch, 1891 (Ent. Nachr. xvii. p. 279).

Hemianax papuensis, Selys, Synopsis Æschn. 1883, p. 15; *et auct.*

Dr. F. Ris*, following Karsch, has lately restored this species to the genus *Anax*. This I consider justified, on the argument that the form of the male inferior appendage is not a generic character, besides being variable, and not at all "triangular" in many specimens. As regards the curvature of Cu_2 and the resultant shape of the "field" between Cu_1 and Cu_2 , although specimens from Western Australia, S. Australia, Victoria, and N.S.W. undoubtedly conform to the arrangement typical of *Anax*, or come very close

* 'Die Fauna Süd-West Australiens,' 1910, p. 435.

to it, yet specimens received by me from Queensland (Plate 4. fig. 8) show almost as much "double-curving" of Cu_2 as can be found in *Hemianax ephippiger*. Cu_2 is essentially variable in form in *A. papuensis*. For that reason I should prefer myself to suppress the genus *Hemianax* altogether, simply considering *papuensis*, and especially *ephippiger*, as the most reduced and specialized types yet attained within the genus *Anax*. Their smaller size and dull coloration are really the *most constant* characters by which these two species differ from the rest, and quite possibly suggested the original proposition of *Hemianax* as a distinct genus.

Larva.—Total length 46, greatest breadth 8.5 mm. across eyes and also across segment 7. **Head.**—Flat above, with large eyes and smooth rounded postocular lobes. **Labium.**—Mentum 7.5×5.5 , reaching to between mesocoxæ, where it narrows to 3 mm. (Plate 5. fig. 14). Median lobe projecting obtusely, subtriangular, carrying a row of short hairs. Lateral lobes much as in *Æschna brevistyla*, but somewhat shorter and broader; apex truncate, but more rounded at the outer angle; tooth of inner angle smaller; movable hook 1.9 mm. (Plate 5. fig. 9). **Thorax.**—Prothorax very narrow and compressed, without lateral spines. Meso- and metathorax strongly built, smooth, no spines; wing-cases 10 mm., that of hind-wing 3 mm. wide; venation very distinct. Legs long and slender, hind femur 10.5 mm.; dark olive-green with many paler bands. **Abdomen.**—Of the usual shape, fairly flat beneath; no dorsal spines; lateral spines on 7–9, those of 7 small, 8 medium, 9 fairly large, reaching to level of middle of 10. **Appendages.**—Superior 5 mm., tip strongly bifid; inferiors 5.5 mm., very sharp (Plate 7. figs. 11, 24). **Involucres:** ♂ superiors 2.4 mm., very sharp; ♂ inferior 0.8 mm., broad, rounded; ♀ 2.3 mm., pointed. **Ovipositor** very small, reaching to middle of 9 or a little beyond (Plate 9. fig. 7). **Colour.**—Rich olive-green, beautifully mottled and marked with numerous spots, bands, and marks, the chief being as follows:—a transparent dark central dorsal band (under which the contractions of the dorsal vessel are often quite visible), broken by pale basal segmental spots; two dark lateral bands consisting of segmental complete portions slightly curved, with large dark reniform basal segmental blotches overlying them on 4–8, and smaller spots lying just internal and basal to them; also a set of small dark spots about the middle of 2–8, halfway between middle line and lateral bands; sometimes a dark sinuous line connects these spots up longitudinally.

Larval Types: ♂ ♀, Coll. Tillyard. (Sydney: ♂ bred Oct. 20th, 1907; ♀ bred Nov. 12th, 1907.)

Life-History.—In most details the account given for *Æschna brevistyla* corresponds closely to the habits of this species. The following are important differences:—

The perfect insect is on the wing very early. I have a female taken on

July 28th, 1910, in very fresh but mature condition. Both sexes may be seen careering about on warm days in August almost anywhere in the bush near Sydney. In August 1905 they were especially common along the beach at Manly. Pairing takes place from August to November, and the male *nearly always accompanies the female while ovipositing*, standing up vertically out of the water with rapidly vibrating wings and supporting her as she lays her eggs. These are of the usual elongate form, slightly larger than the eggs of *Æschna brevistyla*, pale cream- or straw-colour; and are placed carefully by the female in the soft tissues of the leaves or stalks of water-plants. The female often alights on the flat surface of a floating leaf, the male buoying her up, and curves her abdomen completely round and under the leaf, placing the eggs either in the stalk or in the under surface of the leaf itself. This species, therefore, closely approaches many Agrionidæ in its method of oviposition. Only very occasionally do females oviposit alone.

Another important difference is that this species alone of all known Australian *Æschninae* (except *Gynacantha*) lives in absolutely still water. Its chief breeding-places are water-holes, lagoons, and the backwaters and billabongs of rivers. It occurs also on sluggish creeks and rivers, when the larvæ inhabit the deepest parts of large still pools, never being found round the edges, but only in the thick masses of reeds or water-weed nearer the middle.

The larva lives naturally in water-weed, and not on stems or sticks. It preys on Agrionid larvæ, and also on younger individuals of its own species. It is most voracious, and sometimes occurs in immense numbers in small pools. In August 1906, when a small pond near where I was living dried up, the damp water-weed was simply alive with nearly full-fed nymphs of this species, which I picked up by the score. They were quite unable to withstand drought, and within a few days were all dead. This drought caused the species to become quite rare around Sydney for two years; but in 1908 it was fairly common again. This fact, and the fact that half-grown larvæ can often be found in September, causes me to fix *two years* as the normal time for the larva to reach maturity.

The beautiful semitransparent green colouring of this larva is quite unique amongst Australian *Æschninae*, and causes it to be recognisable at a glance when dredged up. Through the integument the contractions of the rectum and the pulsations of the dorsal vessel can be distinctly seen. Curiously enough, very young larvæ are quite differently coloured, being either nearly black or black with broad white bands running transversely, or, in fact, in any stage of piebaldness; some may be dull brown very much like young larvæ of *Æschna brevistyla*. Piebald larvæ are seldom found more than 12 mm. long.

Habitat. The whole continent of Australia; Southern New Guinea. Not yet recorded from Tasmania.

Varieties.—Individual imagines vary much in the clearness and details of the beautifully mottled pattern of the abdomen. The amount of dark brown and pale yellow on 9 and 10 varies greatly, some specimens appearing yellow-tipped when flying, some almost black. Variation occurs also in the shape of the male appendages, both superior and inferior. It is possible that a long series of Western Australian specimens might prove to be constant, the form that I have noted in my short series from that State—viz., that the superior appendages are broader and more leaf-like, and the inferior slightly longer than in those from Eastern Australia.

C. GYNACANTHA SERIES.

M_2 arching strongly up at or near level of pterostigma. Rs unsymmetrically forked well before the level of the pterostigma. $Rspl$ curved concavely to the lower branch of the fork, so as to enclose several rows of cells between. $Mspl$ similarly concave to M_4 . Membranule small. Hind-wing of male angulated, narrower near base than towards nodus; anal triangle either short and broad or long and narrow. Anal appendages long or very long in both sexes. Females with a remarkable fork projecting downwards under segment 10.

Three genera are represented in Australia, and may be distinguished as follows:—

- | | | |
|----|--|--------------------------|
| 1. | } Basilar space reticulated | HELLESCHNA. |
| | | Basilar space free |
| | { Large insects with short, rather wide, three-celled, right-angled anal angle in male. M_2 much arched upwards near pterostigma | GYNACANTHA. |
| 2. | | |

All three genera agree in having a *bifid* fork under segment 10 of the female. This distinguishes them from the closely-allied genera *Triacanthagyna* (trifid fork), *Tetracanthagyna* (four-pronged fork), *Platacantha* (♀ without fork, but with three fine points under 10), and *Cornacantha* (♀ without fork, but with two strong horns under 10). Probably these are all scarcely more than subgenera of *Gynacantha*, but may be retained for systematic purposes as genera.

Genus 1. GYNACANTHA, Rambur.

Characters as given (see above).

Type: *G. gracilis* (Burm.) Handb. Entom. ii. p. 837 (1839).

I am unable to find anywhere that any described larva has been definitely

proved to belong to this genus, though Needham *, in speaking of the larva of *Staurophlebia*, says that it is "very like that of the nymph of *Gynacantha*, and quite different from that of other known *Æschninae*"; these differences being chiefly the "upcurved, sharp, and spinulose" distal margins of the mentum, the bilobed spine-bearing median lobe, and the sharply-pointed hook-like apices of the lateral lobes of the labium.

In February 1910 the late Mr. H. Elgner discovered the larvæ of *Gynacantha rosenbergi* on Banks Island, Torres Straits, and sent me three exuviae, together with a newly-emerged imago taken from one of them. Even without the latter evidence, the extraordinary length of the involucres of the imaginal appendages would at once have determined the genus to which these exuviae belonged. I began to study them, expecting to find a labium similar to that of *Staurophlebia*; but I was quite astounded to find that the labium was almost exactly like that of *Æschna brevistyla*, except that the lateral lobes *each carried a strong and well-developed set of setæ* corresponding in size and position to those found in the nymphs of Libellulidæ. This discovery was very startling and unexpected. If, as seems to me probable this character is to be found in the nymphs of other species of this genus, and possibly in those of allied genera, then Needham's reference to a "*Gynacantha* nymph" is certainly quite inexplicable, and suggests an error in determination.

It is much to be hoped that no time will be lost in searching for other nymphs of this genus, many species of which are abundant enough in tropical regions.

GYNACANTHA ROSENBERGI, Brauer. (Plate 4. fig. 10.)

Brauer, Verh. zool.-bot. Ges. Wien, xvii. (1867) p. 290.

Gynacantha bonguensis, Förster.

Larva.—Total length 41 mm.; greatest breadth 8 mm. across eyes. **Head.**—Flat above, with large eyes and smooth rounded postocular lobes. **Labium.**—Mentum 7.5×4.5 mm., reaching back to well between mesocoxæ, where it narrows to barely 2 mm. (Plate 5. fig. 16). Median lobe very slightly bilobed, with a fairly deep median cleft fringed with a row of short hairs. Lateral lobes shaped as in *Æschna*, but somewhat shorter and wider; apex very flatly truncated, with outer angle scarcely at all rounded and inner angle sharply toothed; no crenulation of inner margin; movable hook 1.6 mm. On a raised ridge running slantwise from below the movable hook across the middle of the lobe is a set of 8-9 very conspicuous setæ, the first apical five of which are long (three reaching to about the outer angle of the apex); the sixth is of medium length, and the last two or three, lying

* 'New Dragonfly Nymphs in U.S. Nat. Museum,' 1904, p. 694.

just basal to the centre of the lobe, are short (Plate 5. fig. 11). *Thorax*.—*Prothorax* not very wide, but not so narrow as in *Anax*; carrying a dorso-lateral and two sublateral spines on each side. *Meso-* and *metathorax* narrow, fairly smooth; *wing-cases* 9 mm., those of hind-wing 2.5 mm. wide. *Legs* very short; hind femur only 7 mm., narrow, not flattened; colour dark brown with pale markings. *Abdomen* of the usual shape, but slenderer and less well-rounded above than in *Æschna*. No dorsal spines; *lateral spines* on 6–9, those of 6 very small, 7–9 medium, that of 9 not reaching to level of middle of 10. *Appendages*.—*Superior* 3.5, slender, bifid at tip; *inferior* very sharp, about the same length or a little shorter (Plate 7. figs. 12, 25). *Involucres*: ♂ *superiors* 3 mm., slender, pointed, reaching nearly to end of appendages; ♂ *inferior* short, broad, triangular, 1 mm.; ♀ very long, 3.2 mm., slender, pointed, reaching *very nearly* to end of appendages. *Ovipositor* large, reaching to near middle of 10 (Plate 9. fig. 3). Colour probably brown or greenish, with dark dorsal and lateral abdominal bands.

Larval Types: ♂ ♀, Coll. Tillyard. (Banks Island, Torres Straits, February 1910; taken by the late Mr. H. Elgner.)

In a note despatched to me with these larvæ, Mr. Elgner mentioned that he found them transforming along the edges of a small lagoon. It would appear, therefore, that this species resembles *Anax* in breeding in still water.

Habitat. In Australia, *G. rosenbergi* is confined to North Queensland and the Northern Territory, where it is quite common. It spreads westward to Singapore and northward to Japan.

Its habits are distinctly crepuscular. During the summer it frequently comes to light, and may be seen darting about the ceiling of a room like a hawk-moth, or hanging motionless on a wall or window-pane. On hot days I have found it flying low in the dense undergrowth of mangrove-swamps edging river estuaries. It keeps very low and is very difficult to capture. It is a very dull, ugly species, and has the habit (fortunately uncommon in Odonata) of developing grease and fungus very badly in the cabinet.

Types: ♂ ♀, Coll. Selys.

GYNACANTHA MOCSARYI, Förster.

Förster, Odon. aus Neu-Guinea, 1898.

This species is rarer than the preceding, but occurs not uncommonly in North Queensland, where I have taken it in dense scrub, in railway-tunnels, and also at light. Two specimens were taken by me in the long tunnel No. 15 on the Cairns–Kuranda railway. They were flying slowly up and down, about noon, and their brilliant green eyes appeared most remarkable in the gloom. It is easily distinguished from *G. rosenbergi* by its slenderer and more graceful form, with segment 3 much pinched, its greenish thorax, the pattern of blue in the form of a cross on segment 2, and the form of the

appendages. In *G. mocsaryi* the male superior appendages are distinctly curved, the apical half of each being flat and leaf-like, length 6.5 mm.; the inferior is 3 mm., triangular at base, but with tip elongated. In *G. rosenbergi* the male superiors are very hairy, long, and straight, 8.5 mm., not much widened towards tips, which end in a tiny point; the inferior only 1.8 mm., narrow subtriangular. In both species the female appendages are very long, and seldom found intact even if the specimen be captured by hand. The auricles of the male are twice as large in *G. mocsaryi* as in *G. rosenbergi*, and the scuta, scutella. and wing-joins are deep blue.

Habitat. North Queensland (Cairns, Kuranda, Cooktown), New Guinea, Lombok.

Types : ♂ ♀, Coll. Förster. (Astrolabe Bay.)

GYNACANTHA DOHRNI, Krüger.

Krüger, Stettin. entom. Zeit. lix. (1898) p. 285.

The claim of this species to inclusion in our ectogenic Australian Odonata rests solely on one specimen in the Leyden Museum, labelled "Cooktown." It is quite likely that it occurs there, but I have never taken it, nor are there any specimens of it amongst the very large number of *Gynacantha* from North Queensland in the Macleay Museum, Sydney.

Easily distinguished from the two preceding species by its smaller size, much denser reticulation, excessively slender abdomen (1-2 much swollen, with large auricles in male), and by the slender superior appendages of the male carrying a small inner projection or tubercle near their bases.

Types : ♂ ♀, Coll. Krüger. (Sumatra.)

Genus 2. AUSTROGYNACANTHA, Tillyard *.

Characters as given (see above).

Type : *Austrogynacantha heterogena*, Tillyard.

It is unnecessary to repeat the argument of my previous paper in favour of the recognition of this genus. In the narrowing of the anal triangle of the male, and the more regularly curved M_2 under the pterostigma, not to mention the distinct differences in the shape of the abdomen, we have strong and constant characters of full generic value. Since 1908 I have fortunately been able to see with my own eyes this very beautiful insect in flight and to watch its habits. These are quite unlike those of a *Gynacantha*. It flies in broad daylight, and has the habits of a small *Austroaeschna*, besides possessing a coloration somewhat similar to that of some members of the same genus in general effect.

* "On the new Genus *Austrogynacantha*," Proc. Linn. Soc. N.S.W. xxxiii. (1908) p. 423.

The genus is monotypic, and must be regarded as a specialized offshoot from the main *Gynacantha*-stem. Though now apparently confined to Australia, it must be included in the ectogenic series, of which it forms an essential part.

AUSTROGYNACANTHA HETEROGENA, *Tillyard*. (Plate 4. fig. 9.)

Tillyard, *loc. cit.* p. 428 (♀, Selys MSS., name not published).

Habitat. Cooktown, Rockhampton, Brisbane. A pair taken by Mr. Hacker last January at Clayfield Creek, Brisbane, while I was out collecting with him, are now in my collection, together with a fine series sent by Mr. Olive from Cooktown. I saw this species also at Sherwood and Indooroopilly, suburbs of Brisbane, but failed to capture it. It flies rather high round trees and bushes. The colour-scheme is lemon-yellow on dark brown, with a tinge of green on the thorax, and is very striking.

Types: ♂ ♀, Coll. Tillyard (Cooktown, February 1908); ♀, Coll. Selys (Rockhampton).

Genus 3. HELIÆSCHNA, *Selys*.

Characters as given (see above).

Type: *Heliaeschna fuliginosa*, Selys.

Distinguishable at once from the two foregoing genera by having its basilar space reticulated. The form of M_2 is rather that of *Austrogyacantha*, while the anal triangle of the male is of intermediate shape. The fork under segment 10 of the female is two-pronged.

HELIÆSCHNA SIMPLICIA, *Karsch*.

Karsch, Ent. Nachr. 1891.

The claim of this insect to inclusion in the Australian Odonate fauna rests, like that of *Gynacantha dolrni*, on a single specimen in the Leyden Museum, labelled "Cooktown." Both insects range from Sumatra to Borneo, and their occurrence at Cooktown is quite possible, though I have never met with either of them, nor seen them in any collections from Queensland. Is it not possible that there has been a mistake in the labelling, or that specimens taken in the islands may have been brought to Cooktown and sent to Leyden from there?

Comparative Table for the known Larvæ of Australian Æschinæ.

NAME.	MEASUREMENTS.		MENTUM.			ABDOMEN.				
	Total length.	Greatest breadth of abdomen.	Size.	Reaching to	Median lobe	Dorsal spines	Lateral spines	Superior appendages	Inferior appendages	♀ ovipositor reaching to
<i>Austrophlebia costalis</i> , Tillyard.	48	9	8×6	between 2nd coxæ	slightly bilobed, one pair tubercles	absent	3-4 small, 5 medium, 6-9 large	long, pointed	long, pointed	well beyond end of 10
<i>Telephlebia godeffroyi</i> , Selys	27.5	5	6.5×4	between 1st coxæ	obtuse triangular projection	absent, large tubercle on 10	8-9 very small	short, nodding	medium, pointed	—
<i>Dendroæschna conspersa</i> , Tillyard.	32	7	5×4	just to 2nd coxæ	slightly convex	absent	6-9 large	short, truncate, dentate	long, pointed	a little beyond end of 9
<i>Austroæschna unicornis pulchra</i> , Tillyard.	31*	7	7×3.5	well between 2nd coxæ	slightly bilobed, one pair tubercles	absent	5 small, 6-9 medium	fairly long, pointed	fairly long, pointed	well beyond end of 10
<i>Austroæschna longissima</i> , Martin.	36	7	6×4.5	just to 2nd coxæ	slightly bilobed, one pair tubercles	absent	7-9 large	long, pointed	long, pointed	about middle of 10
<i>Austroæschna multipunctata</i> , Martin.	37	7	7.5×4	between 2nd and 3rd coxæ	slightly convex, one pair tubercles	absent	6-9 small	fairly long, pointed	fairly long, pointed	just beyond end of 9
<i>Austroæschna parvistigma</i> , Selys.	35	6.5	—	between 2nd and 3rd coxæ	slightly convex, one pair tubercles	absent	6-9 small	fairly long, pointed	fairly long, pointed	end of 9
<i>Austroæschna anacantha</i> , Tillyard.	33	6.5	5.5×4	between 1st and 2nd coxæ	slightly convex, one pair tubercles	absent	6 small, 7-9 medium	fairly long, pointed	fairly long, pointed	just beyond end of 9
<i>Austroæschna atrata</i> , Martin	37	7.5	6×5.2	just to 2nd coxæ	very slightly bilobed, two pairs tubercles	absent	5 small, 6-9 medium	fairly long, pointed	fairly long, pointed	—
<i>Notoæschna sagittata</i> (Martin).	37.5	8.5	4.5×5	between 1st coxæ	very obtuse, triangular projection	small on 4-10	5-9 very large	short, spiny, pointed	long, spiny, pointed	end of 9 (very small)
<i>Anax papuensis</i> (Burrm.) ...	46	8.5	7.5×5.5	between 2nd coxæ	distinctly convex	absent	7 small, 8 medium, 9 large	very long, bifid	very long, pointed	middle of 9 (very small)
<i>Æschna brevislyla</i> , Ramb....	39	7.5	7.5×6	between 2nd and 3rd coxæ	bilobed	absent	7 small, 8-9 medium	long, bifid	long, pointed	two-thirds of 9 (very small)
<i>Gynacantha rosenbergi</i> , Brauer.	41	7	7.5×4.5	well between 2nd coxæ	very slightly bilobed	absent	6 small, 7-9 medium	very long, truncate	very long, pointed	near middle of 10
<i>Austropetalia patricia</i> , Tillyard.	34	11.	5×4.8	between 1st coxæ	slightly convex	small double tubercles on 4-8	2-8, conspicuous fin-like lobes	short, narrowly truncate	medium, pointed	just beyond end of 9

* Measurement of type ♀. A second ♀, from Ebor, was 36×7 mm.

APPENDIX A. Material Studied.

Austropetalia patricia, Tillyard. 3 ♂, 3 ♀. Blue Mountains, N.S.W.: 1 ♀, Leura, Nov. 1903 (G. A. Waterhouse); 1 ♀ emerging, Leura, Nov. 1908 (K. Brown); 1 ♀, Woodford, Oct. 1912 (G. J. Waterhouse); 2 ♂, Katomba, Nov. 1912 (C. Goldfinch); 1 ♂, Katomba, Nov. 1912 (R. J. T.).
Exuviae: 1 ♀, Leura Cascades, Nov. 1908 (K. Brown).

Austrophlebia costalis, Tillyard. 9 ♂, 11 ♀. 1 ♀, N.S.W., circ. 1870 (Australian Museum, Sydney); 2 ♀, Dorrigo, N.S.W., Nov. 1911; 1 ♂, Dorrigo, Dec. 1911; 6 ♂, 6 ♀, Mount Tambourine, Q., Dec. 1912–Jan. 1913; 1 ♀, Hill Top, N.S.W., Feb. 1912 (E. Cheel); 1 ♀, Herberton, N.Q., Jan. 1911 (F. P. Dodd); 1 ♂, Killarney, Q., Jan. 1913 (E. J. Dumigan); 1 ♂, Stanwell Park, N.S.W., Feb. 1913 (C. Goldfinch).
Exuviae: 1 ♂, Dorrigo, Dec. 1911; 2 ♂, 1 ♀, Stanwell Park, Feb. 1913 (G. A. Waterhouse). *Living Larva*: 1, half-grown, Mount Tambourine, Dec. 1912.

Telephlebia godeffroyi godeffroyi, Selys. 6 ♂, 9 ♀, Blue Mountains (Medlow, Woodford), Dec.–Jan. 1907–1912 (H. J. Carter, G. A. Waterhouse, and self). 6 ♂, 3 ♀, Ebor, N.S.W., Jan. 1912. 2 ♀, Hornsby, N.S.W., Jan. 1911. I have also examined a very long series in the Macleay Museum, Sydney University, taken on the Blue Mountains, 1860–1870.
Exuviae: 1 ♂, Ebor, Jan. 1912. *Living Larva*: 1, half-grown, Leura, Oct. 1906.

Telephlebia godeffroyi brevicauda, n. subsp. 10 ♂, 14 ♀, Mount Macedon, Vic., Jan. 1906 (G. Lyell and S. Angel). 1 ♂, 2 ♀, Jindabyne, N.S.W., Jan. 1906. 1 ♀, Mount Kosciusko, N.S.W., Mar. 1912 (Dr. A. J. Turner).

Telephlebia godeffroyi cyclops, n. subsp. 1 ♂, Dorrigo, Dec. 1911. 1 ♀, Mount Tambourine, Jan. 1913.

Telephlebia asthenes, n. sp. 1 ♀, Mount Tambourine, Nov. 1911 (H. Hacker).

Dendroaeschna conspersa, Tillyard. 4 ♂, 2 ♀, Mittagong, N.S.W., Mar. 1905. 10 ♂, 6 ♀, Lily Vale, N.S.W., Mar.–May 1907–8. 1 ♂, 1 ♀, Glenbrook, N.S.W., Mar. 1910. 8 ♂, 6 ♀, Ourimbah, N.S.W., Apr. 1908. 1 ♂, National Park, N.S.W., Mar. 1907. 4 ♂, 7 ♀, Heathcote, N.S.W., Apr. 1909. 1 ♂, Hornsby, Apr. 1911. 1 ♂, 1 ♀, Hill Top, Mar. 1913.
Exuviae: 1 ♀, Lily Vale, Feb. 1905. 6 ♂, 7 ♀, Auburn, N.S.W., Mar. 1909. 18 ♂, 17 ♀, Heathcote, Apr. 1909. *Living Larvae*: 3 small, Lily Vale, Dec. 1906.

Austroaeschna tripunctata, Martin. 6 ♂, 1 ♀, Alexandra, Vic., Dec. 1906. 1 ♀, Jindabyne, N.S.W., Jan. 1906. 1 ♂, Dorrigo, Dec. 1911.

Austroaeschna weiskei, Förster. 1 ♂, Kuranda, N.Q., Jan. 1913 (F. P. Dodd).

Austroæschna forcipata, Tillyard. 5 ♂, 4 ♀, Kuranda, Jan. 1905-8 (E. Allen, F. P. Dodd, and self). 2 ♂, 1 ♀, Cooktown, N.Q., Feb. 1908 (E. A. C. Olive).

Austroæschna unicornis unicornis, Martin. 1 ♂, Mount Macedon, Vic., Jan. 1906 (G. Lyell).

Austroæschna unicornis pulchra, Tillyard. 5 ♂, 2 ♀, Mittagong, Mar. 1905. 2 ♂, 1 ♀, Lily Vale, April-May 1907. 6 ♂, 8 ♀, Ebor, Jan. 1912. *Exuvie*: 1 ♀, Ebor, Jan. 1912; 1 ♀, Stanwell Park, Feb. 1913 (G. A. Waterhouse).

Austroæschna inermis, Martin. 3 ♂, 1 ♀, Mount Kosciusko, N.S.W., Jan. 1914 (A. J. Turner).

Austroæschna longissima, Martin. 2 ♂, 1 ♀, Mittagong, Mar. 1905. 2 ♂, 3 ♀, Lily Vale, Mar. 1907. 3 ♂, Heathcote, Feb. 1909. 8 ♂, 2 ♀, Ourimbah, Apr. 1908. 1 ♀, Launceston, Tas., Dec. 1908. 1 ♂, Adelaide, S.A., Jan. 1912 (S. Angel). 1 ♂, 2 ♀, Herberton, N.Q., Feb. 1910, Jan. 1911 (F. P. Dodd). 1 ♂, Nattai River, N.S.W., Mar. 1913. *Exuvie*: 1 ♀, Ebor, Jan. 1912. *Living Larvæ*: 2 ♂, 1 ♀, Lily Vale, Nov. 1907, nearly full-grown. 1 three-quarter grown, Heathcote, Oct. 1908. 1 ♂, National Park, Nov. 1904, bred out Jan. 1905.

Austroæschna parvistigma parvistigma, Selys. 10 ♂, 7 ♀, Zeehan, Tas., Jan. 1905 (K. Finlay). 2 ♂, 1 ♀, Burnside, S.A., Dec. 1906 (S. Angel). 1 ♂, 1 ♀, Launceston, Tas., Dec. 1908. 10 ♂, 8 ♀, Ebor, Jan. 1912. 1 ♂, Hill Top, Mar. 1913. *Exuvie*: 1 ♂, Launceston, Tas., 1 ♀, St. Patrick's River, Tas., Dec. 1908.

Austroæschna parvistigma flavomaculata, n. subsp. 1 ♂, Mount Kosciusko, N.S.W., Jan. 1914 (A. J. Turner).

Austroæschna multipunctata, Martin. 3 ♂, 1 ♀, Mount Macedon, Vic., Jan. 1906 (G. Lyell). 1 ♂, 3 ♀, Mount Kosciusko, Jan. 1906. 5 ♂, 3 ♀, Medlow, N.S.W., Jan. 1910. 2 ♂, 5 ♀, Dorriggo, Nov.-Dec. 1911. 27 ♂, 16 ♀, Ebor, Jan. 1912. 1 ♂, 5 ♀, Mount Tambourine, Jan. 1913. 1 ♂, Hill Top, Mar. 1913. 2 ♂, 3 ♀, Hornsby, Dec. 1910. *Exuvie*: 1 ♂, Medlow, Jan. 1910; 4 ♀, Woodford, N.S.W., Feb. 1913 (G. A. Waterhouse). *Living Larvæ*: Numbers dredged from creeks at Leura and Medlow, Oct. 1909; ♀ bred Oct. 1909, ♂ bred Dec. 1909.

Austroæschna atrata, Martin. 2 ♂, 5 ♀, Katoomba, N.S.W., Feb. 1905. 1 ♂, Medlow, Jan. 1910. 2 ♂, 3 ♀, Alexandra, Vic., Dec. 1906. 3 ♂, 2 ♀, Ebor, Jan. 1912. *Exuvie*: 1 ♂, Ebor, Jan. 1912.

Austroæschna anacantha, Tillyard. 27 ♂, 24 ♀, Armadale, Bridgetown, Wilgarrup, Margaret River, W.A., Dec. 1906-Jan. 1907. 5 ♂, 8 ♀, Waroona, W.A., Jan. 1910, Feb. 1912 (G. F. Berthoud). *Exuvie*: 20 ♂, 27 ♀, Waroona, Feb. 1912 (G. F. Berthoud).

Austroæschna tasmanica, n. sp. 1 ♂, Hobart, Tas., Feb. 1892 (Hobart Museum).

Notoeschna sagittata (Martin). 1 ♂, 5 ♀, Alexandra, Vic., Dec. 1906. 1 ♀, Jindabyne, Jan. 1906. 1 ♂, Blackheath, N.S.W., Nov. 1908. Var. *geminata*: 27 ♂, 16 ♀, Ebor, Jan. 1912. *Exuviae*: 1 ♂, 2 ♀, Ebor, Jan. 1912.

Æschna brevistyla, Rambur. Numerous ♂ ♀, Sydney and district, 1905–1913; South-Western Australia (Bridgetown, Busselton, Wilgarrup, Waroona), 1905–1911 (G. F. Berthoud and self); Tasmania (Launceston, Hobart), Dec.–Jan. 1908–9; Dorriggo, Dec. 1911; Ebor, Jan. 1912. 3 ♂, 1 ♀, Mount Tambourine, Q., Dec. 1912. Also series from Levin, N.Z., Nov. 1911 (G. Howe); 2 ♂, Kermadec Is. *Exuviae*: Numerous ♂ ♀ from Sydney, 1905–1913. *Living Larvæ*: Numbers dredged from creeks in Sydney district; 5 ♂, 6 ♀ bred.

Anax guttatus (Burm.). 6 ♂, Atherton, N.Q., Jan. 1905. 5 ♂, 7 ♀, Cooktown, N.Q., Jan. 1908. 1 ♂, 2 ♀, Port Darwin, Dec. 1908 (F. P. Dodd). 3 ♂, 3 ♀, Cairns, 1907–11 (E. Allen).

Anax gibbosulus, Rambur. 1 ♂, 2 ♀, Port Darwin, Dec. 1908 (F. P. Dodd); 1 ♀, Atherton, Jan. 1905.

Anax papuensis (Burm.). Numerous ♂ ♀, Sydney district, 1905–1913; North Queensland (Atherton, Kuranda, Cairns, Cooktown, Townsville), 1905–1911; W. Australia (Perth, Busselton, Bridgetown), Jan. 1907; Victoria (Alexandra, Mount Macedon, Melbourne), Dec. 1906. 2 ♂, Pallal, N.S.W., Dec. 1910. 3 ♂, Dorriggo, Dec. 1911. 1 ♂, 1 ♀, Mount Tambourine, Dec. 1912. 2 ♂, 1 ♀, Brisbane, Jan. 1913. *Exuviae*: Numbers from Sydney district. *Living Larvæ*: Numbers dredged from ponds and water-holes around Sydney; 8 ♂, 7 ♀ bred.

Gynacantha rosenbergi, Brauer. 2 ♂, 3 ♀, Kuranda, Dec. 1904. 6 ♂, 8 ♀, Cairns, 1905–1911 (E. Allen). 5 ♂, 9 ♀, Cooktown, Jan.–Feb. 1908 (E. A. C. Olive and self). 1 ♂, 4 ♀, Coen, N.Q. (H. Hacker). 2 ♂, 3 ♀, Cape York, Nov. 1909 (H. Elgner). 6 ♂, 10 ♀, Banks Is., Torres Straits, Feb. 1910 (H. Elgner). 2 ♂, 3 ♀, Port Darwin, Dec. 1908 (F. P. Dodd). *Exuviae*: 1 ♂, 2 ♀, Banks Is., Feb. 1910 (H. Elgner).

Gynacantha mocsaryi, Förster. 4 ♂, 3 ♀, Kuranda, N.Q., Jan. 1905 (F. P. Dodd and self). 4 ♂, 4 ♀, Cooktown, Jan. 1908 (E. A. C. Olive and self). 1 ♂, Cape York, Nov. 1909 (H. Elgner).

Austrogynacantha heterogena, Tillyard. 6 ♂, 6 ♀, Cooktown, Feb. 1908 (E. A. C. Olive). 1 ♂, 1 ♀, Brisbane, Jan. 1913 (H. Hacker).

N.B.—Except where otherwise specified, all the above material has been taken by myself and has been in my collection. Probably nearly half of the total number of specimens papered and set has been sent out to various correspondents or to Australian Museums.

APPENDIX B.

Description of a new Form of *Telephlebia*. By HERBERT CAMPION.

TELEPHLEBIA GODEFFROYI TILLYARDI, n. subsp., *Campion*.

Total length 70.5 mm.; length of abdomen alone 54 mm.

Total alar expanse 109 mm.; length of hind-wing alone 53 mm.

Length of pterostigma 5.5 mm.

Fore-wings with 30-32 antenodals and 27-29 postnodals.

General coloration dark brown above, light brown below. Labium dark brown; lateral lobes black externally. Exposed portions of mandibles black. Face and antennæ golden. Frons much produced anteriorly; a large blackish oval spot on the summit, not wider than the space lying between the antennæ. Vertex black; ocelli garnet. Occipital triangle pale brown. Thorax dark brown above, yellowish-brown at sides; no humeral stripes.

Wings hyaline, with a broad band of russet-brown extending along the anterior portion from the base to the apex: between the base and the nodus this band lies below the costal space, and has an irregular outline posteriorly; at the nodus it widens out to reach the costa, and, after escaping a small hyaline space beyond the prolongation of the subcosta, becomes a well-defined stripe following the margin of the wing to the apex, and exactly filling the two rows of cells lying nearest the costa. Reticulation black. Pterostigma rose-pink: brace-vein oblique, cutting across one or two of the transverse nervures lying between the radius and M_1 . Membranules brownish-white. The fork of the radial sector for the most part filled with three rows of cells. Triangle of fore-wing 6-celled; median space traversed by 7 or 8 nervures. Triangle of hind-wing 5- or 6-celled; 8 or 9 nervures crossing the median space. Anal loop long, narrow, containing 10 or 11 cells; two other large enclosures between the anal loop and the base of the wing.

Legs light brown, with a ring of black at the apex of the femur.

Abdominal segments 1 and 2 inflated: 3 constricted basally: 4 to 7 cylindrical: 8 and 9 dilated ventrally: 9 with a pair of two-jointed apical filaments below, the basal joint stout and dark brown, the apical joint shorter, very slender, pale brown; the filaments separated by a strong median pale brown spine: 10 with the apical margin produced ventrally into a semicircular plate carrying on its border numerous irregular denticulations; prolongation of segment large and hairy. Anal appendages shorter than segment 10, slender, rounded, pointed, blackish. Ovipositor-spine blackish-brown, reaching the level of the middle of segment 10.

Queensland: 1 adult ♀ (*F. P. Dodd*). Kuranda, near Cairns.

Holotype in the British Museum (Register No. 1907—129).

I have pleasure in naming this fine species after my friend Mr. R. J. Tillyard, in recognition of the important additions which he has made to our knowledge of Australian Dragonflies. It is readily distinguished from *T. godeffroyi*, de Selys, by its larger size and by the absence of humeral yellow stripes. The prolongation of the subcosta will at once separate it from *Austrophlebia costalis*, Tillyard, to which it seems to be very similar in general appearance.

EXPLANATION OF THE PLATES.

PLATE 1.

Fig. 1. Small creek on Mount Tambourine, showing straight stretch along which several *Austrophlebia costalis* were taken and its speed of flight measured. A larva was taken under a small flat rock near top end of this stretch.

Fig. 2. Curtis's Falls and bathing-pool, Mount Tambourine. Larval skins of *Austrophlebia costalis* were seen on the large rock on which a man is sitting, and one was secured from the stalk of a native arum growing near by.

PLATE 2.

Fig. 1. *Austrophlebia costalis*, Tillyard. ♂ imago.

2. " " " ♀ imago.

3. " " " ♂ exuviae.

4. *Telephlebia godeffroyi godeffroyi*, Selys. ♂ exuviae.

(All figures natural size.)

PLATE 3.

Fig. 1. *Telephlebia godeffroyi godeffroyi*, Selys, ♂.

2. " " " " var. *hyalina*, ♂. Notice the broken right superior appendage.

3. " " *brevicauda*, n. subsp., ♂.

4. " " *cyclops*, n. subsp., ♂.

5. " " " ♀.

(All figures natural size.)

PLATE 4.

Fig. 1. Wings of *Austropetalia patricia*, Tillyard, ♂.

2. " *Austrophlebia costalis*, Tillyard, ♂.

3. " *Telephlebia godeffroyi cyclops*, n. subsp., ♂.

4. " " *asthenes*, n. sp., ♀.

5. " *Dendroaeschna conspersa*, Tillyard, ♂.

6. " *Austroaeschna multipunctata*, Martin, ♂.

7. " *Notoaeschna sagittata* (Martin) Tillyard, ♂.

8. " *Anax papuensis* (Burm.), ♂. (Blackbutt, Qu.), showing unusual curving of Cu_2 .

9. " *Austrogynacantha heterogena*, Tillyard, ♂.

10. " *Gynacantha rosenbergi*, Brauer, ♂.

PLATE 5.

- Fig. 1. *Austrophlebia costalis*, Tillyard. Median and left lateral lobes of labium of nymph.
 2. *Telephlebia godeffroyi godeffroyi*, Selys. " " "
 3. *Austroæschna unicornis pulchra*, Tillyard. " " "
 4. " *longissima*, Martin. " " "
 5. " *multipunctata*, Martin. " " "
 6. " *anacantha*, Tillyard. " " "
 7. *Dendroæschna conspersa*, Tillyard. " " "
 8. *Notoæschna sagittata* (Martin). " " "
 9. *Anax papuensis* (Burm.). " " "
 10. *Æschna brevistyla*, Ramb. " " "
 11. *Gynacantha rosenbergi*, Brauer. " " "
 12. *Austropetalia putricia*, Tillyard. " " "
 13. *Austroæschna atrata*, Martin. " " "
 14. *Anax papuensis* (Burm.). Natural position of nymphal mask.
 15. *Æschna brevistyla*, Ramb. " " "
 16. *Gynacantha rosenbergi*, Brauer. " " "

(Figs. 1-13, $\times 20$; figs. 14-16, $\times 9$.)

PLATE 6.

- Fig. 1. *Austrophlebia costalis*, Tillyard. Natural position of nymphal mask.
 2. *Telephlebia godeffroyi godeffroyi*, Selys. " " "
 3. *Dendroæschna conspersa*, Tillyard. " " "
 4. *Austroæschna unicornis pulchra*, Tillyard. " " "
 5. " *longissima*, Martin. " " "
 6. " *multipunctata*, Martin. " " "
 7. " *atrata*, Martin. " " "
 8. " *anacantha*, Tillyard. " " "
 9. *Notoæschna sagittata* (Martin). " " "
 10. *Austroæschna unicornis pulchra*, Tillyard. Ovipositor of female nymph.
 11. " *longissima*, Martin. " "
 12. " *multipunctata*, Martin. " "

(Figs. 1-9, $\times 9$; figs. 10-12, $\times 24$.)

PLATE 7.

- Fig. 1. *Austrophlebia costalis*, Tillyard. Dorsal view of appendages of male nymph.
 2. *Telephlebia godeffroyi godeffroyi*, Selys. " " "
 3. *Dendroæschna conspersa*, Tillyard. " " "
 4. *Austroæschna unicornis pulchra*, Tillyard. " " female nymph.
 5. " *longissima*, Martin. " " "
 6. " *multipunctata*, Martin. " " male nymph.
 7. " *anacantha*, Tillyard. " " "
 8. " *atrata*, Martin. " " "
 9. *Notoæschna sagittata* (Martin). " " "
 10. *Æschna brevistyla*, Ramb. " " "
 11. *Anax papuensis* (Burm.). " " "
 12. *Gynacantha rosenbergi*, Brauer. " " "
 13. *Austrophlebia costalis*, Tillyard. Lateral view " "
 14. *Telephlebia godeffroyi godeffroyi*, Selys. " " "

Fig. 15. *Dendroaeschna conspersa*, Tillyard. Lateral view of appendages of male nymph.

- | | | | | |
|-----|--|---|---|---------------|
| 16. | <i>Austroaeschna unicornis pulchra</i> , Tillyard. | " | " | female nymph. |
| 17. | " <i>longissima</i> , Martin. | " | " | " |
| 18. | " <i>multipunctata</i> , Martin. | " | " | male nymph. |
| 19. | " <i>anacantha</i> , Tillyard. | " | " | " |
| 20. | " <i>atrata</i> , Martin. | " | " | " |
| 21. | <i>Notoaeschna sagittata</i> (Martin). | " | " | " |
| 22. | " " " | " | " | female nymph. |
| 23. | <i>Æschna brevistyla</i> , Ramb. | " | " | male nymph. |
| 24. | <i>Anax papuensis</i> (Burm.). | " | " | " |
| 25. | <i>Gynacantha rosenbergi</i> , Brauer. | " | " | " |

s, superior larval appendage; *i*, inferior lateral do.; *ms*, involucre of superior male imaginal appendage; *mi*, involucre of inferior do.; *t*, dorsal tubercle; *sp*, spine.

(All figures $\times 10$, except nos. 3 and 15, $\times 24$.)

PLATE 8.

Fig. 1. *Austrophlebia costalis*, Tillyard, ♂. Appendages, dorsal view.

- | | | | | | |
|-----|--|--|-----------------------------------|--------------|----------------------------------|
| 2. | " | " | " | " | lateral view. |
| 3. | " | " | " | ♀. | Dentigerous plate, lateral view. |
| 4. | " | " | " | " | dorsal view. |
| 5. | " | " | " | " | Stylus of ovipositor. |
| 6. | " | " | " | " | Triangle of hind-wing. |
| 7. | <i>Telephlebia godeffroyi godeffroyi</i> , Selys, ♂. | Appendages, | dorsal view. | | |
| 8. | " | " | " | " | lateral view. |
| 9. | " | " | <i>brevicauda</i> , n. subsp., ♂. | Appendages, | dorsal view. |
| 10. | " | " | " | " | lateral view. |
| 11. | " | " | <i>cyclops</i> , n. subsp., ♂. | Appendages, | dorsal view. |
| 12. | " | " | " | " | lateral view. |
| 13. | " | " | <i>godeffroyi</i> , Selys. | Pterostigma. | |
| 14. | " | " | <i>brevicauda</i> , n. subsp. | " | |
| 15. | " | " | <i>cyclops</i> , n. subsp. | " | |
| 16. | " | <i>asthenes</i> , n. sp. | " | | |
| 17. | " | <i>godeffroyi godeffroyi</i> , Selys. | Triangle of hind-wing. | | |
| 18. | " | " | <i>brevicauda</i> , n. subsp. | " | " |
| 19. | " | " | <i>cyclops</i> , n. subsp. | " | " |
| 20. | " | <i>asthenes</i> , n. sp. | " | " | |
| 21. | " | <i>godeffroyi godeffroyi</i> , Selys. | Region of nodus. | | |
| 22. | " | " | <i>brevicauda</i> , n. subsp. | " | " |
| 23. | " | " | <i>cyclops</i> , n. subsp. | " | " |
| 24. | " | <i>asthenes</i> , n. sp. | " | " | |
| 25. | " | <i>godeffroyi godeffroyi</i> , Selys, ♀. | Dentigerous plate. | | |
| 26. | " | <i>asthenes</i> , n. sp., ♀. | Dentigerous plate. | | |
| 27. | " | <i>godeffroyi godeffroyi</i> , Selys. | Front, dorsal view. | | |
| 28. | " | " | <i>cyclops</i> , n. subsp. | " | " |
| 29. | " | " | <i>godeffroyi</i> , Selys. | Membranule. | |
| 30. | " | " | <i>brevicauda</i> , n. sp. | " | |
| 31. | " | " | <i>cyclops</i> , n. sp. | " | |
| 32. | " | <i>asthenes</i> , n. sp. | Obsolescent membranule. | | |

(Figs. 1-5, 7-12, 25-26, $\times 20$; figs. 6, 13-24, 27-32, $\times 9$.)

PLATE 9.

- Fig. 1. *Austrophlebia costalis*, Tillyard. Ovipositor of female nymph.
 2. *Notoæschna sagittata* (Martin). " " "
 3. *Gynacantha rosenbergi*, Brauer. " " "
 4. *Austroæschna anacantha*, Tillyard. " " "
 5. *Austropetalia patricia*, Tillyard. " " "
 6. *Æschna brevistyla*, Ramb. " " "
 7. *Anax papuensis* (Burm.). " " "
 8. *Austropetalia patricia*, Tillyard, ♂ imago. Anal appendages, dorsal view.
 9. " " " " " " lateral view.
 10. " " " " " Lateral view of ventral part of segment 2.
 11. *Austroæschna tasmanica*, n. sp., " Anal appendages, dorsal view.
 12. " " " " " " lateral view.
 13. *Notoæschna sagittata* (Martin), ♀ imago. End of abdomen, lateral view.
 14. " " " " " " ventral view.
 15. " " " ♂ imago. Segment 2, ventral view.
 16. " " " nymph. Lateral view of segments 5-9.
 17. } Variations of venation in the region of the nodus from the wings of *Austrophlebia*
 18. } *costalis*, Tillyard, to show tendency towards the *Telephlebia*-type:—17, from
 19. } right hind-wing of a ♀ ; 18, from right fore-wing of a ♀ ; 19, from right fore-
 20. } wing of a ♂ ; 20, from left fore-wing of type ♂. (Pigmentation omitted.)
 21. *Austropetalia patricia*, Tillyard, ♂ imago. Penis.
 22. *Notoæschna sagittata* (Martin). Ovum.
 23. *Austroæschna longissima*, Martin. Ovum.
 24. *Austropetalia patricia*, Tillyard. Ovum.

aur.=auricle, *sp.*=spine.

(Figs. 1-21, × 10 ; figs. 22-24, × 24.)

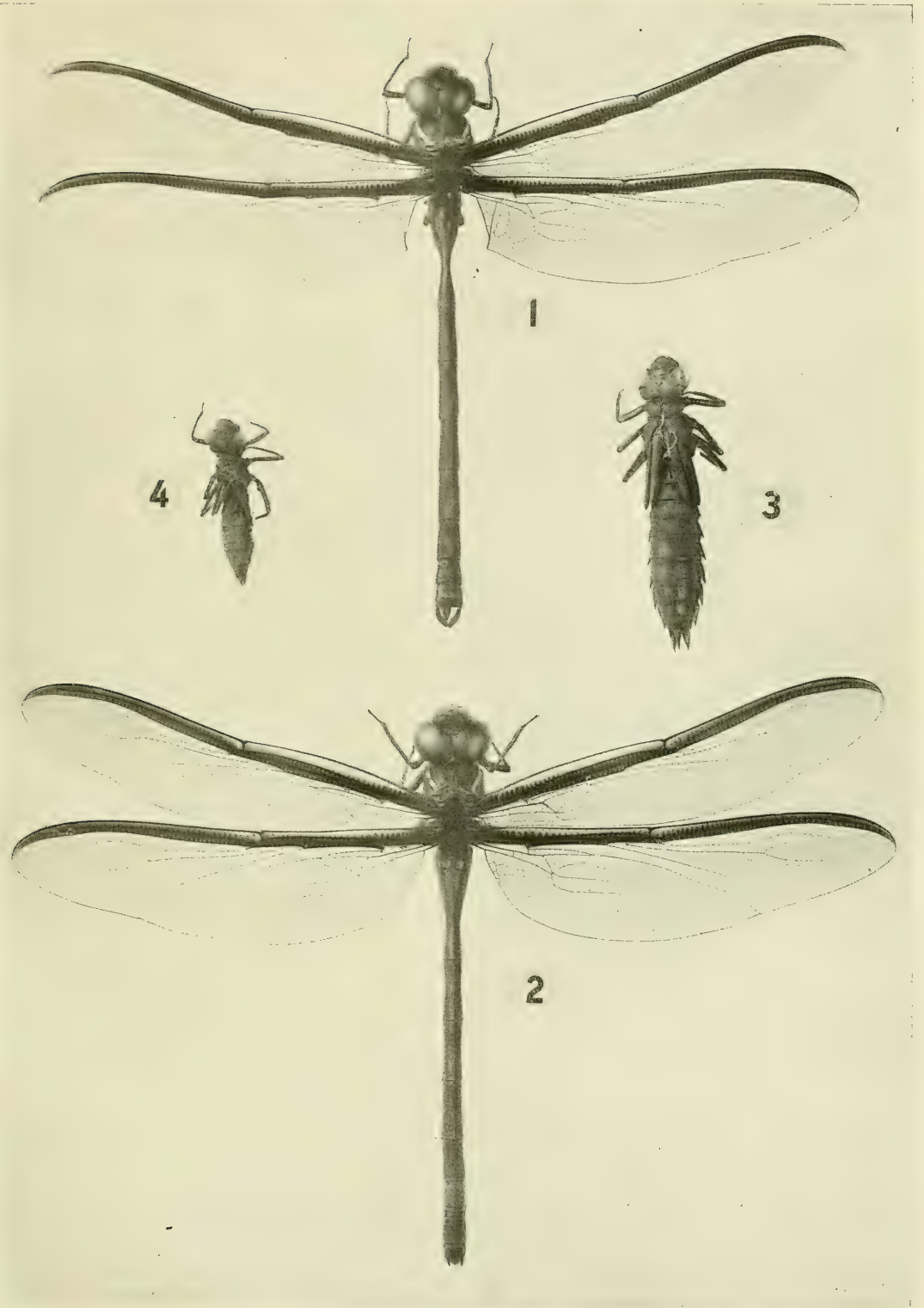


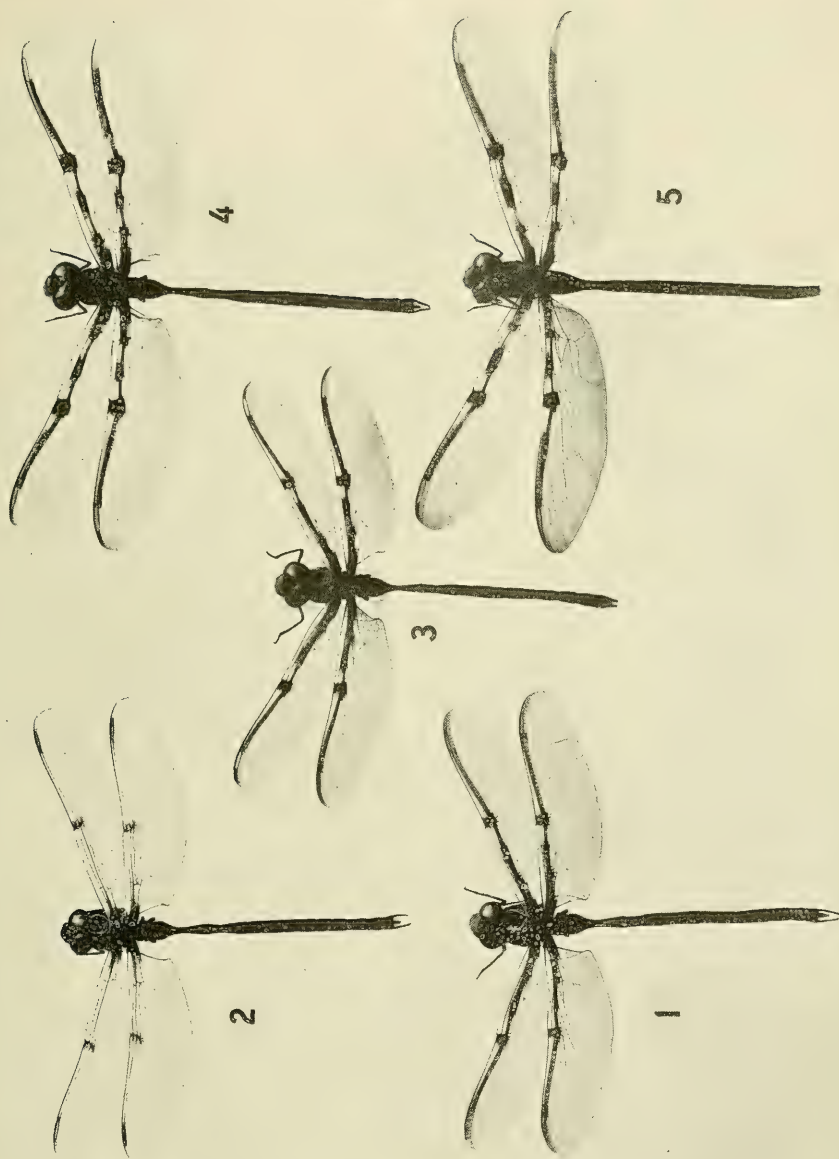
FIG. 2.

SCENES ON MOUNT TAMBOURINE.



FIG. 1.

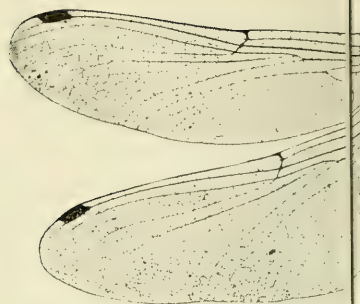




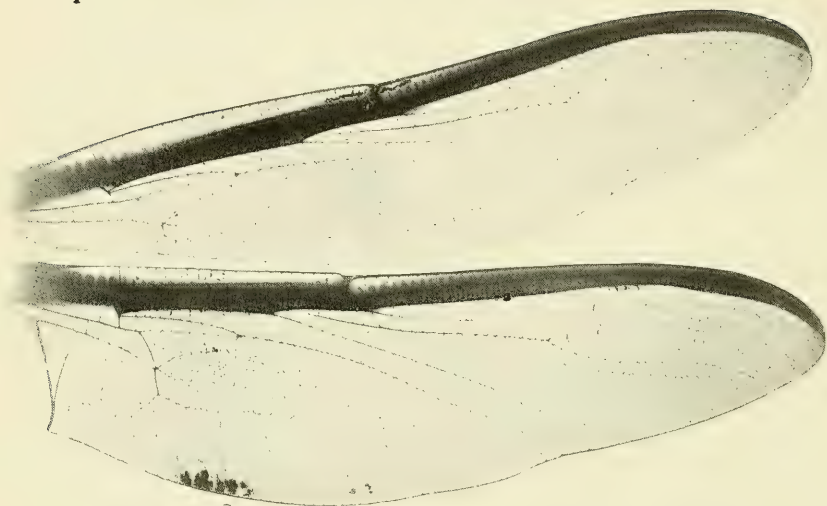
AUSTRALIAN AESCHNINÆ.



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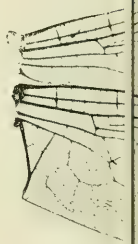
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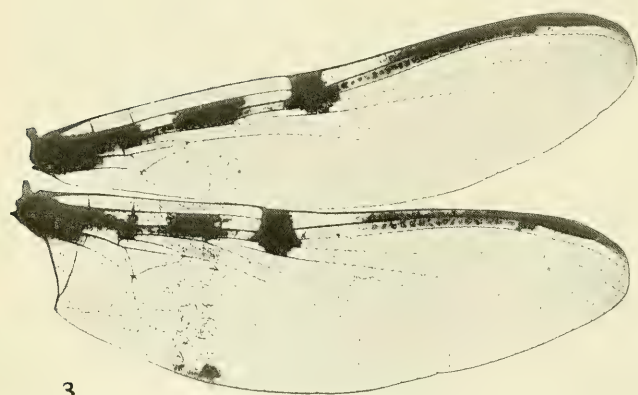
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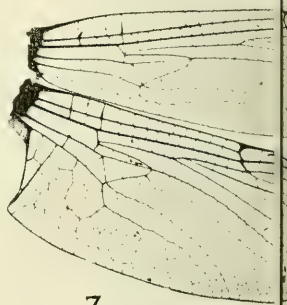
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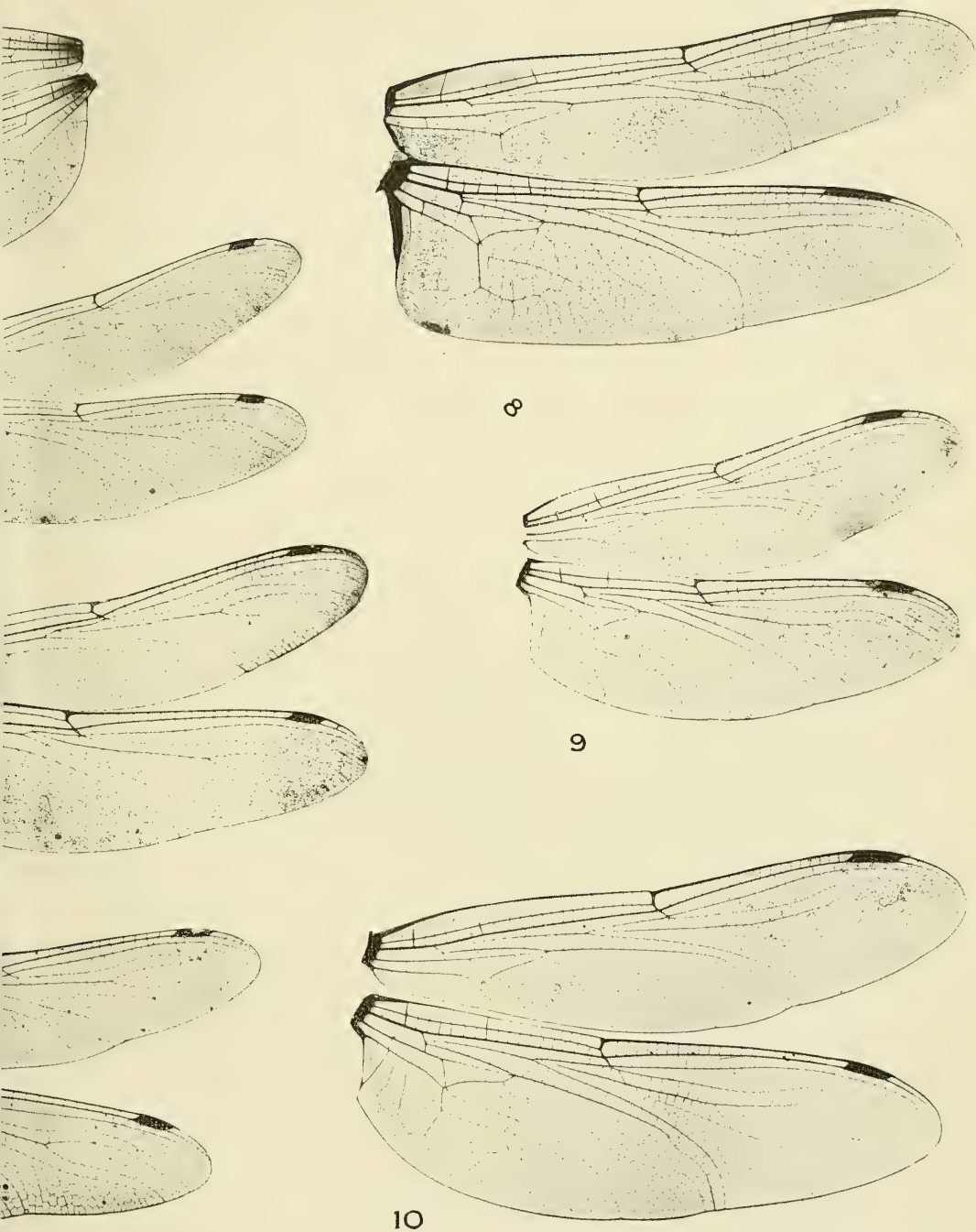
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7

R. J. T. photo.

WINGS OF AUST





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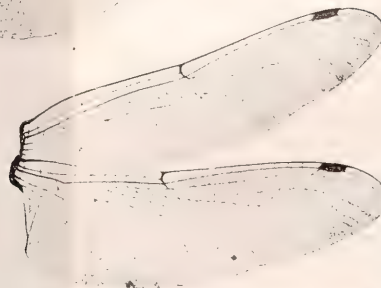
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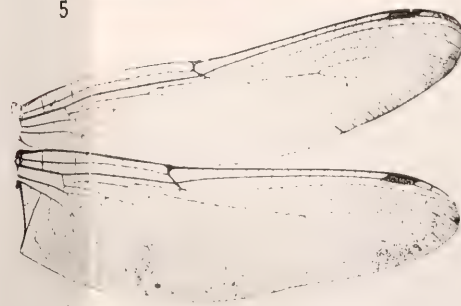
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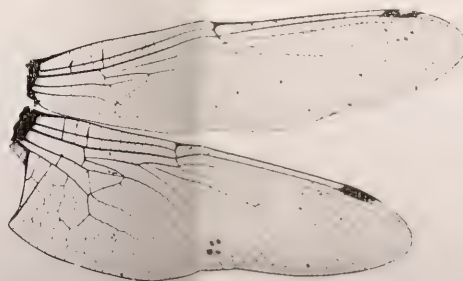
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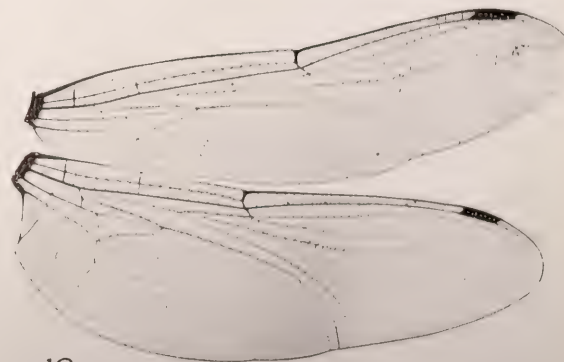
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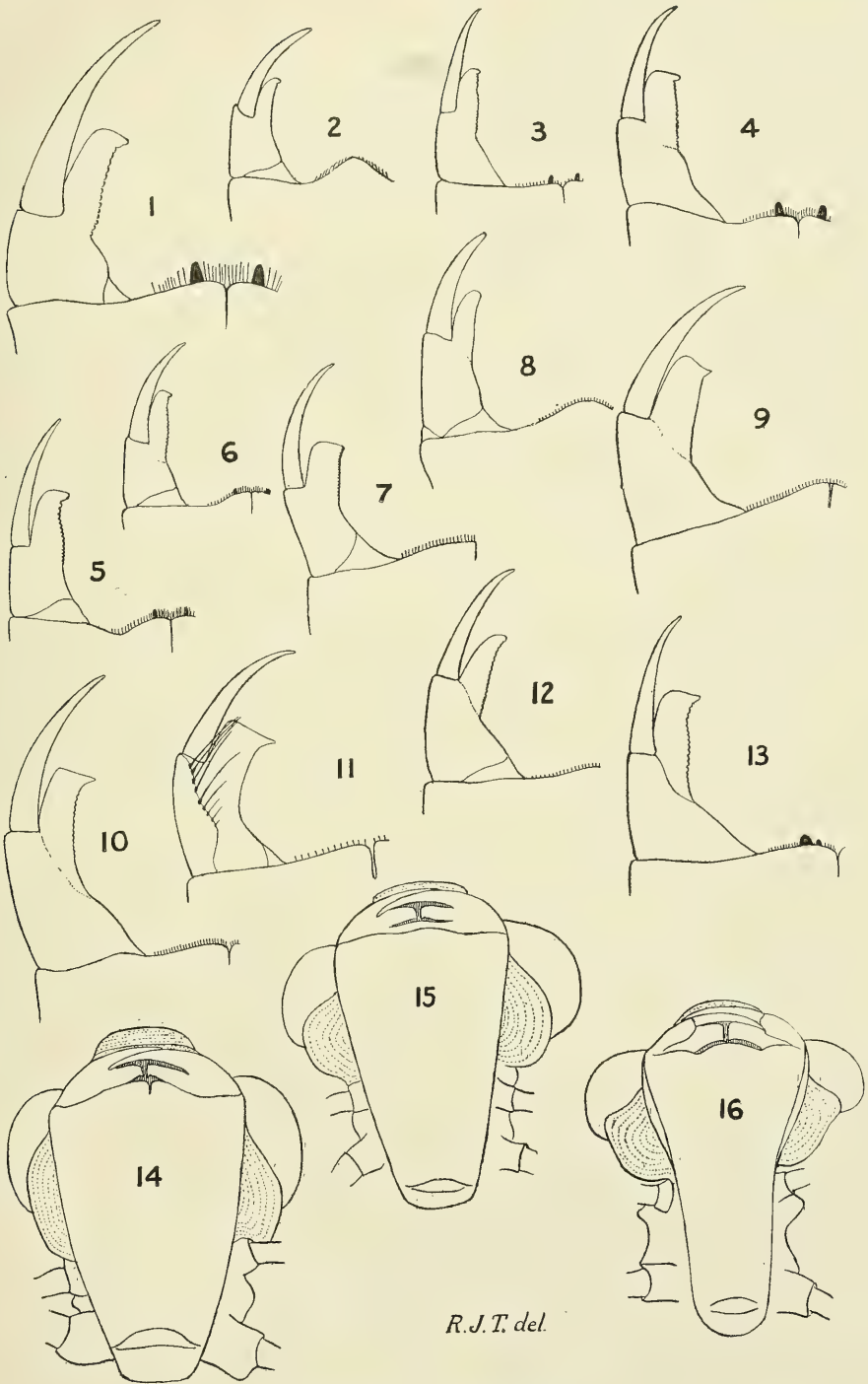


10

R. J. T. photo.

WINGS OF AUSTRALIAN ÆSCHNINÆ.

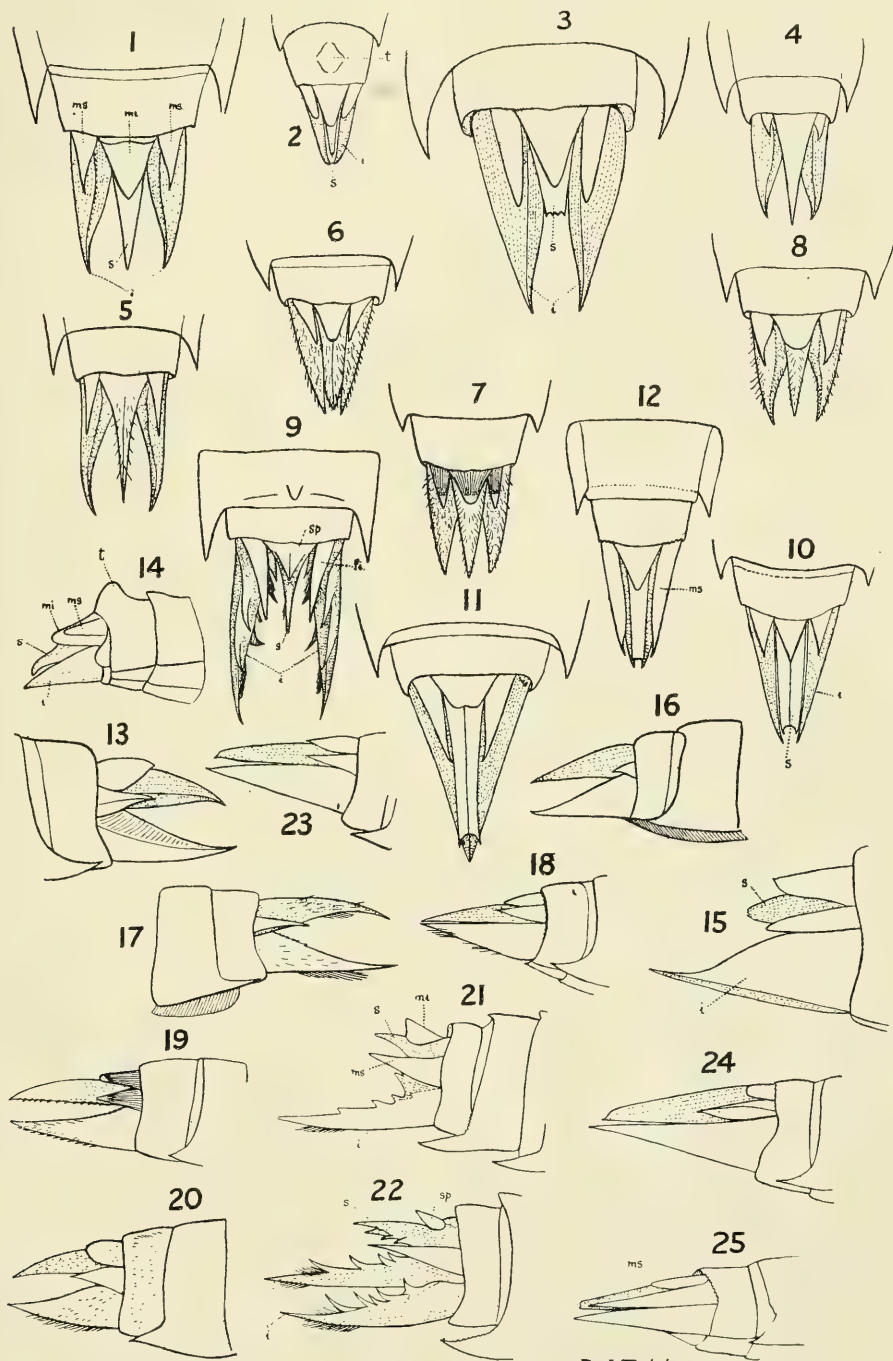
Grout, photo.



AUSTRALIAN AESCHNINÆ.

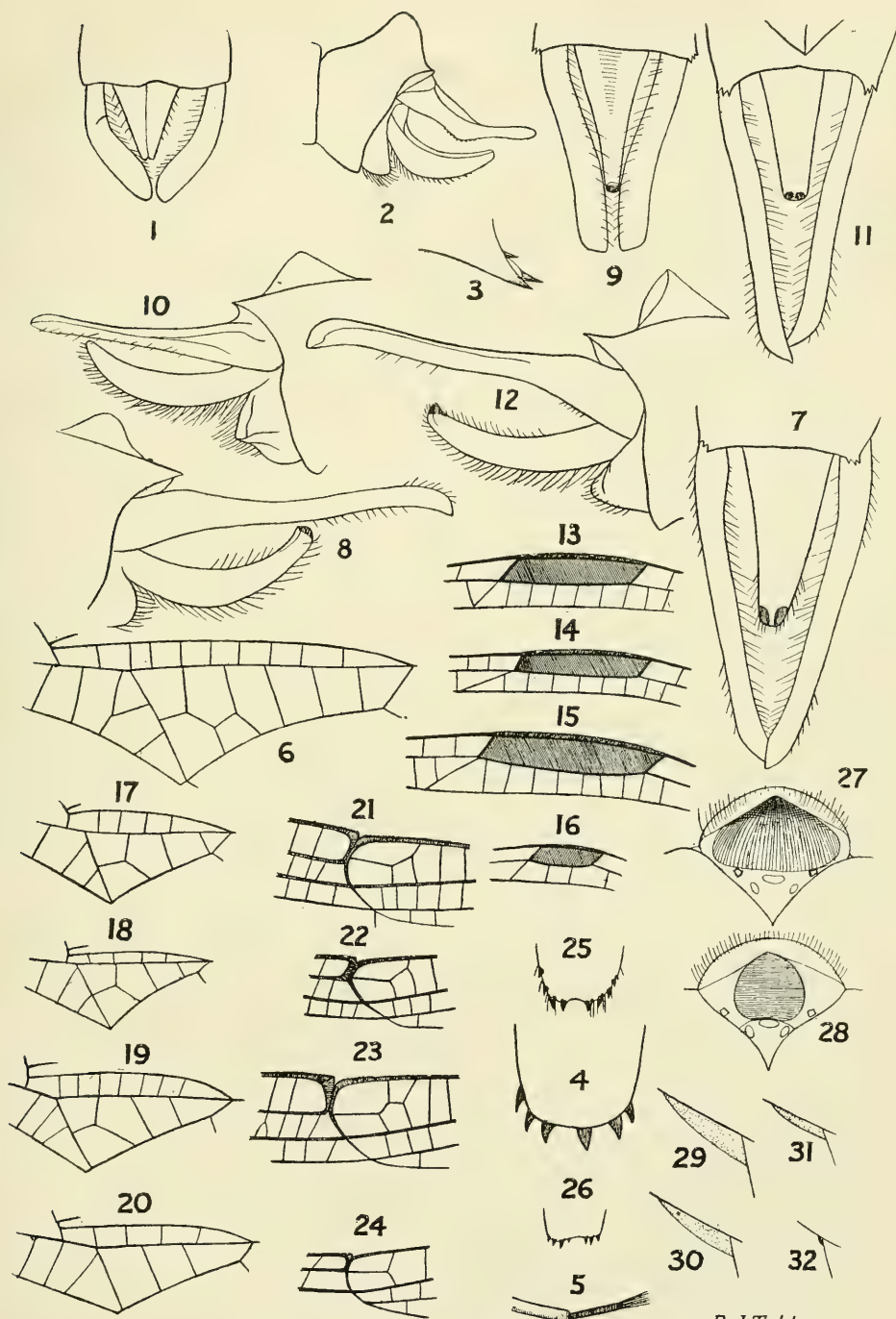


AUSTRALIAN AESCHNINÆ.

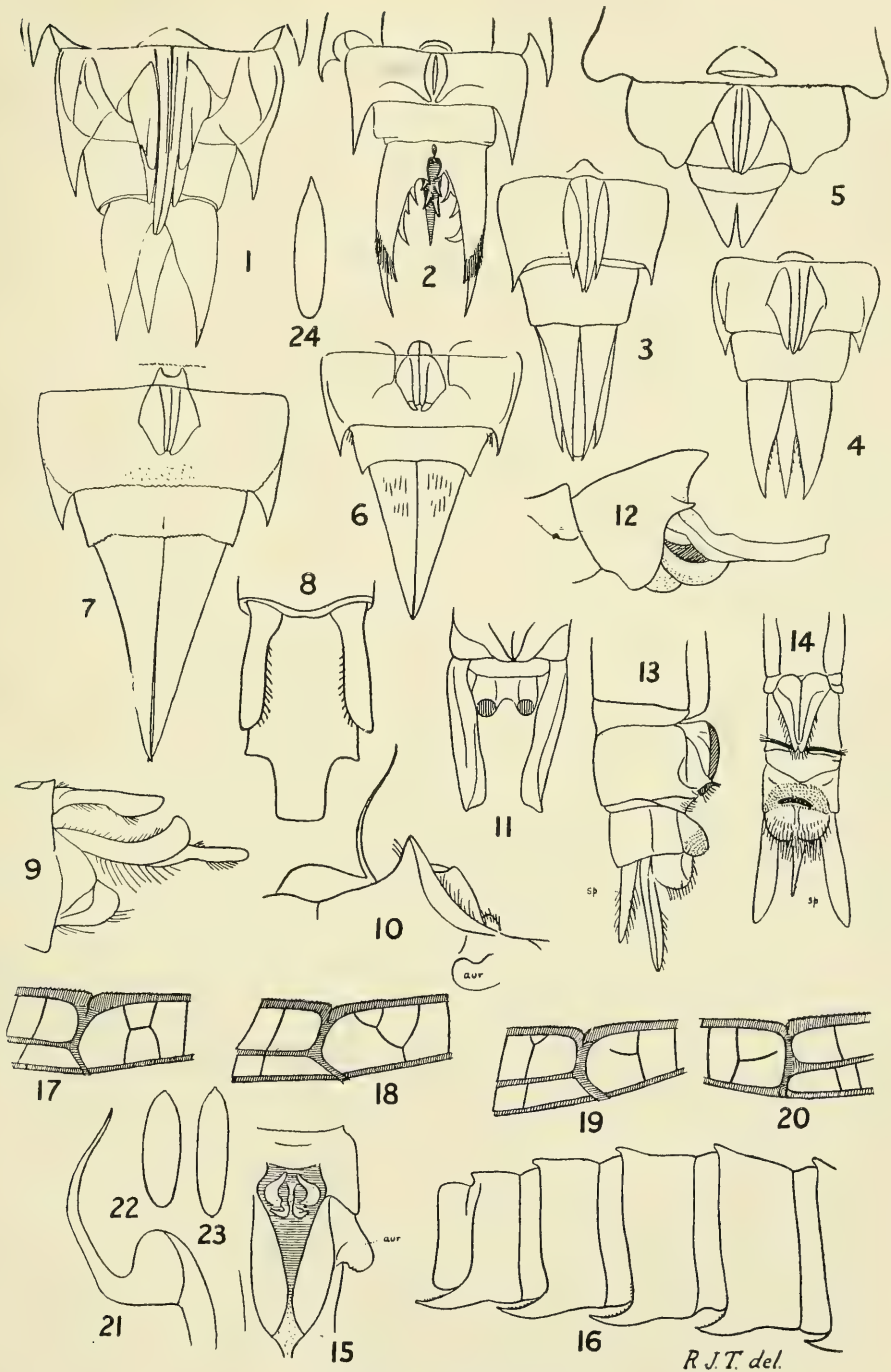


R J. T. del.

AUSTRALIAN ÆSCHNINÆ.



R. J. T. del



AUSTRALIAN AESCHNINÆ.

A new Species of Enteropneusta, *Ptychodera pelsarti**, from the Abrolhos Islands. By W. J. DAKIN, D.Sc., F.L.S., Professor of Biology in the University of West Australia.

[Percy Sladen Trust Expedition to the Abrolhos Islands under the leadership of Prof. W. J. DAKIN.]

(PLATES 10 & 11.)

[Read 6th April, 1916.]

INTRODUCTION.

NOTWITHSTANDING the investigations that have been made up to date, the coast of Western Australia is almost an unknown region so far as marine biology is concerned. No Enteropneusta were known from this side of Australia—as a matter of fact, none have been recorded from the north, west, or southern coasts of the island continent. It was particularly interesting, therefore, to find a number of specimens of an Enteropneust on one of the Abrolhos Islands. The specimens were discovered by the author of the paper on the lagoon side of the Pelsart Island Reef at its southern extremity. It was originally intended to publish an account of the islands before any papers on the fauna. As the work was, however, rather of the nature of a preliminary examination, and a second expedition is intended this year, the description of the islands will be withheld until our return.

At the place where the specimens were found the coral reef is submerged at high-tide and only just uncovered at low-water. The rise and fall of the tide is only about 2–3 feet. The specimens occurred in a deposit of sand, gravel, and shell-fragments, which had collected in hollows in the smooth water-worn reef-flat. They were frequently found under small loose pieces of coral, with the anterior extremity just projecting out of the sand. About fifteen specimens were obtained by sifting the gravel between the fingers under water. They varied somewhat in size, but none could be called small, the average size being about 4 inches (10 cm.) when extended.

The specimens belong to a new species of the genus *Ptychodera*. They are not very far removed from some of the varieties of *Ptychodera flava* now known, and at first there was some doubt in my mind as to whether this new form might not better rank as a subspecies. As, however, it appears quite

* The species is named after Pelsart, whose ship was wrecked on the Abrolhos Islands in the year 1629. The island on which the specimens were found is also named after Pelsart, whose adventures at the Abrolhos Islands were of the most thrilling character.

distinct in many ways and occupies a somewhat isolated position geographically, it is better to consider it a distinct species at once.

The genus *Ptychodera* was first recorded from the Australian coast by Professor J. P. Hill in 1893—the species coming from the coast of New South Wales. This Eastern form was named *Ptychodera australiensis*. Since that time a number of new species and varieties of the genus have been recorded, and one of these was also from the East Australian coast—*Ptychodera hedleyi*.

In 1901, however, Spengel* revised the nomenclature of Enteropneusta, and as a result confined the genus *Ptychodera* to the species formerly placed in the group Chlamydothorax. As a result of this reshuffling of names, *Pt. australiensis*, Hill, became *Balanoglossus australiensis* (Hill) and *Pt. hedleyi*, Hill, became *Glossobalanus hedleyi* (Hill).

Ptychodera pelsarti, n. sp., from the Abrolhos Islands, is thus the only species of the genus so far known from Australia, although all three Australian Enteropneusta belong to the same family—the Ptychoderidae, Spengel.

Ptychodera flava, Eschscholtz, 1825, is the oldest-known Enteropneust. The description of the original specimens from the Marshall Islands in the Pacific was, unfortunately, defective, and no Enteropneusta from this locality have since been investigated. In 1897 †, however, Willey described specimens found by him on a small islet inside the reef of New Caledonia as probably identical with *Pt. flava* of Eschscholtz, but suggested the name *Pt. caledoniensis* until the Marshall Island *Pt. flava* was re-examined. The next mention of *Pt. flava* was in Hill's Report ‡ on the Enteropneusta of Funafuti. In 1903, Spengel published a paper § on an Enteropneust from one of the Sandwich Islands—Laysan,—which resembled closely Willey's specimens of *Pt. flava* from New Caledonia. This form is described as *Pt. laysanica*. Finally, in the same year, Punnett described the Enteropneusta from the Laccadive Islands and Maldiv Islands, and regarded several forms as new varieties of *Ptychodera flava*.

The present position is, therefore, to be summed up as follows :—

Ptychodera flava. Type insufficiently described.

Habitat: Marshall Isles. Pacific.

Pt. flava, var. *caledoniensis*,
or *Pt. caledoniensis*.

Habitat: New Caledonia. Pacific.

Pt. flava, var. *laysanica*,
or *Pt. laysanica*.

Habitat: Laysan Isle. Pacific Ocean.

* "Die Benennung der Enteropneusten-Gattungen," Zool. Jahr., Syst. Abt. Bd. xv. Hft. i. 1901.

† "On *Ptychodera flava*, Eschscholtz," Q. J. M. S. vol. xl. n. s., 1897.

‡ Memoirs Australian Museum, vol. iii.

§ Zool. Jahr., Anat. Abt. Bd. xviii. 1903.

<i>Ptychodera flava</i> ,		
var. from Funafuti.	Habitat: Funafuti.	Pacific Ocean.
<i>Pt. flava</i> ,	}	Habitat: Laccadive and Maldive Isles. Indian Ocean.
var. <i>parva</i> .		
var. <i>laccadivensis</i> .		
var. <i>maldivensis</i> .		
var. <i>saxicola</i> .		
var. <i>gracilis</i> .		
var. <i>muscula</i> .		
var. <i>cooperi</i> .		
<i>Pt. pelsarti</i>	Habitat: Abrolhos Islands.	Southern Indian Ocean.

To complete the list, the remaining species of the genus *Ptychodera*, as now limited, may be added :—

<i>Ptychodera erythræa</i>	Habitat: Red Sea.
<i>Ptychodera bahamensis</i>	Habitat: Bahamas.
<i>Ptychodera viridis</i>	Habitat: Maldive Islands.
<i>Ptychodera asymmetrica</i>	

PTYCHODERA PELSARTI.

Colour, Measurements, and External Form.

Like most species of the Ptychoderidæ, *Pt. pelsarti* (Pl. 10. fig. 1) is littoral and occurs in very shallow water. Its habitat, like that of *Balanoglossus australiensis*, is loose, gravelly sand, under and around stones in sheltered pools between tide-limits.

The colour is a nearly uniform pale yellow, the hepatic cæca not being too decidedly marked by colour, but only a little darker (brownish), and this only anteriorly. The body of the animal, particularly the posterior region, is translucent, hence the contents of the alimentary canal—shell and gravel—can be quite easily seen in the living animal. The animals are somewhat delicate, and care must be taken to keep them complete while removing them from the sand.

Size.

No accurate measurements were made of the animals when alive. This is much to be regretted, because the amount of contraction taking place after fixation and preservation is extremely great. The average size of the animals captured was about 10 cm.

The size of the 10 cm. specimen after fixation is approximately 50–60 mm.

Proboscis.

The proboscis is short, and, in preserved specimens, is only equal to the width of the collar. In life the proboscis is constantly being extended, so that its length is greater than its width. The extended length, however,

was never more than twice the width of the collar. In the preserved specimens the length of the proboscis varies from 2.5 mm. to 4 mm.

Collar.

In both the living and the preserved specimens the surface of the collar can be subdivided into five characteristic regions, as in other species of *Ptychodera*. The most anterior of these regions occupies a little more than half the collar. In front it possesses a crinkled margin, surrounding the narrow neck or base of the proboscis. The diameter of the collar diminishes slightly towards the end of this anterior region, and ultimately we reach the second region—a circular groove,—which, as we shall see later, is also well-marked histologically. This groove is succeeded by a circular cushion, behind which is a deep furrow in which the epithelium forms a smaller cushion. Lastly, we come to the fifth region, which forms the posterior margin of the collar.

The total length of the collar in the preserved specimens, in which the proboscis was from 2.5–4 mm. in length, varied from 2.3–4 mm. That is to say, the collar and proboscis, in the contracted state, are almost equal in length.

Trunk.

Branchiogenital Region.—This region is characterised by the possession of genital pleura, which are attached anteriorly to the collar (Pl. 10. fig. 1). These genital wings are slightly different from those of *Pt. flava* in their point of origin. They do not arise quite so far ventrally, and in no case is there such an exposed branchial region of the alimentary canal as that figured by Willey for *Pt. flava* *.

The genital pleura do not overlap, nor are they infolded. For the greater part their edges are just in contact in the median line. They remain for some distance constant in size, for a distance approximately equal to the combined lengths of the proboscis and collar. The wings are, in fact, just as large where they adjoin the collar as at any other point in this region of greatest development. A few millimetres in front of the anterior hepatic cæca the pleura commence to decrease in size. This decrease is, however, very gradual, and thus the pleura overlap the most anterior hepatic cæca. Finally, nothing is left of the genital wings but two ridges, which can be traced posteriorly for some distance at the sides of the hepatic cæca.

The Reproductive Organs occur in the pleura.

The length of the branchiogenital region is approximately 6–7 mm.

Hepatic Region.—The length of the hepatic region is about 15 mm. The sacculæ occur as paired elevations separated by a groove, the larger ones being lobulated. Their greatest development is just a little distance behind

* Willey, 'Zoological Results, based on Material' etc. part iii. 1899, plate 26.

the genital pleura. The most anterior large saccules are much darker in colour than those following, the posterior saccules being but little different in colour from the pale yellow of the body generally.

Caudal Region.—This region varies greatly in length. It is delicate and often breaks off, so that it is frequently missing in preserved specimens.

A very delicate ridge can just be traced running along the mid-dorsal line, corresponding in position to the dorsal nerve-trunk. Parallel to this, and slightly more distinct, are two ridges (one on either side of the mid-dorsal line) which are continuous anteriorly with the genital pleura. In the preserved specimens the entire animal—from the postbranchio-genital region, at least, to the end of the caudal portion is marked by close annulation.

ANATOMY.

Proboscis.

The epidermis of the proboscis (Pl. 10. fig. 2, *Epid.*) varies between .10 and .18 mm. in thickness. A conspicuous nerve-fibre layer lies at its base and is almost one-fifth to one-quarter the total thickness of the epidermis. There is a thin basement-membrane below the epidermal layer, and underlying this a conspicuous, although delicate, layer of circular muscle-fibres, which reaches its greatest development towards the base of the proboscis (Pl. 10. fig. 2, & Pl. 11. fig. 5). Between the nerve and circular muscle-layers is a prominent system of blood-lacunæ—the vascular network of the proboscis.

The Longitudinal Muscle Fibres of the proboscis are arranged, as is usually the case, in radial bundles (fig. 5, *Rad.M.*), which extend distally to the end of the glomerulus and are marked out by radial fibres. These bundles touch as they near the centre of the proboscis. At about the level of the glomerulus the longitudinal muscle-fibres encroach upon this central organ. More proximally, however, the muscles leave a space—the proboscis cœlom (figs. 2 & 5, *Pr.Co.*)—which surrounds the stomochord, glomerulus, etc., the organs forming the central complex of the proboscis (figs. 2, 4, & 5). This proboscis cœlom becomes divided dorsally, and towards the neck of the proboscis, into two pouches, which lie to right and left of the middle line (fig. 5, *Dor.P.C.*). As in other Ptychoderidæ the division is due to the presence of the pericardium (fig. 5, *Per.*). The two halves of the proboscis cœlom so formed dorsal to the central complex open generally to the exterior at the base of the proboscis by two dorsal and equal proboscis-pores (Pl. 11. figs. 8 & 9, *P.p.*).

The ventral portion of the proboscis cœlom is continued posteriorly into a kind of cœcum (fig. 2, *V.p.c.*), which also becomes separated into right and left halves—in this case by a septum, which becomes more distinct and better developed as one passes posteriorly (figs. 6 & 8, *V.p.s.*). Both the anterior and posterior edges of this septum are free, so that transverse sections through the extreme end of the ventral proboscis cœcum show no septum.

The splanchnic epithelium of the proboscis cœlom is not everywhere distinct, but it becomes particularly definite in the ventral cœcum referred to above. This is an outstanding feature of all sections through this structure. The cells are very regular in appearance and columnar or often cubical, with large nuclei which stain intensely. The ventral cœcum projects, of course, into the buccal cavity, where it appears as a small but very distinct protuberance. It is the structure which was named the "blumenkohlähnliches Organ" by Spengel, on account of its lobose appearance in *Ptychodera erythroa*. Willey termed it the Racemose Region, and in several varieties of *Ptychodera flava* it appears to possess some few small round elevations. Such is not the case in *Pt. pelsarti*—at least, in the specimens examined. The epithelium of the buccal cavity is also modified where it covers this organ, making it still more conspicuous in sections. One characteristic feature of the ventral proboscis cœcum (and consequently of the so-called Racemose Organ) of *Pt. pelsarti* is that it is very much compressed laterally (fig. 8), the septum itself consisting merely of two layers of epithelium (Splanchnotheca) with a most delicate layer of tissue and blood-spaces between them. The total thickness of the septum is only .03 mm. The relation of the nuchal skeleton to the ventral proboscis cœcum is another feature of some importance, and will be referred to below. The anterior border of the ventral septum runs obliquely backwards from the central complex.

Proboscis pores.

There are two proboscis pores, as in *Ptychodera flava* varieties, opening one on either side of the middle line. Willey states (1891) that *Pt. flava* is characterised by the *constant* occurrence of paired proboscis pores, although considerable variation seems to exist in the manner of communication between the pores and the proboscis cœlom. Six variations were described, but in all cases there were two pores—two actual openings.

The proboscis pores open into terminal ectodermal vesicles, which are connected by tubes with the dorsal cœlomic canals. Now, in *Pt. pelsarti*, as in *Pt. flava*, the proboscis pore is a wide orifice almost equal in diameter to the terminal vesicle itself (Pl. 11. figs. 8 & 9, *V.p.p.*). In two specimens examined by serial sections there was some variation in the cœlomic canals.

In specimen A two proboscis pores were to be seen, one of which communicated with the cœlom directly. The other pore also opened into a terminal vesicle, but this was not in communication with its corresponding dorsal cœlomic canal. The two cavities were separated by chondroid tissue (fig. 9). This condition is somewhat like that of Series II. of Willey.

In specimen B, both sides of the animal were similar, the dorsal cœlomic canals running without any block into terminal vesicles, which opened by proboscis pores to the exterior.

Further variations are probably to be found, but I am unwilling to sacrifice the few remaining specimens for the purpose of following this out. It appears to be of little systematic importance.

Punnett also finds variations in connection with the proboscis pores in the varieties of *Ptychodera flava*, captured at the Maldive and Laccadive Islands. There may be two pores, both in communication by canals with dorsal coelomic pouches; there may be only one pore in open communication with the coelom, although the two pores are present; there may be only one proboscis pore. The side of the animal—right or left,—marked by the different conditions, varies just as much. Evidently every possible condition may occur.

Stomochord.

In *Pt. flava*, according to Willey, the Pericardium, Glomerulus, and Stomochord are *exactly co-extensive*. Unfortunately, no longitudinal sections are figured showing this. In *Pt. pelsarti* the pericardium and stomochord are co-extensive, but the glomerulus extends over both, forming a kind of cap to the "central complex" of the proboscis (Pl. 10. fig. 2, *glom.*). The stomochord (fig. 2, *St.*) may be divided into three regions:—(a) anterior interglomerular region, (b) middle or cæcal region, (c) the posterior nuchal region.

The anterior portion of the structure (see fig. 2) is without any lumen whatever. The latter becomes evident a little distance anterior to the ventral septum of the proboscis, but there are isolated traces of it in front of this. The stomochord is almost circular in section at its distal extremity. More posteriorly it becomes elliptical in section, with the long axis directed dorso-ventrally (fig. 4, *St.*). This leads next to the cæcal region, where the stomochord becomes wider transversely than dorso-ventrally (Pl. 10. fig. 6, *St.*). Two very well-developed lateral pouches are given off at this point.

In sections, the central lumen of the cord may be seen quite close to the dorsal wall of the stomochord, whilst laterally two very well-marked lateral diverticula are evident (fig. 6, *St.p.*). It cannot be said that any ventral "Blindsack" of Spengel is present at all in this form. Two well-marked lateral projections of the cord are quite as distinct as the lateral pouches in *Glossobalanus ruficollis*, *Spengelia*, and *Balanoglossus australiensis*. No ventral blind sac is to be seen. The lumen of the stomochord extends distally for some distance after the lateral pouches are given off. Posteriorly to the ventral diverticula, the stomochord loses its chorda-like character. The lumen becomes larger and larger (Pl. 11. fig. 8, *St.c.*). In transverse section the structure is almost quadrangular in shape, and numerous gland-cells appear on all sides. Finally, as the opening of the stomochord into the throat-cavity is approached, the cord becomes very much compressed dorso-ventrally and drawn out laterally, until it becomes almost as wide as it is in the region of the lateral diverticula. The cells of the ventral wall become

quite short and columnar-epithelial like. Eventually these become exceedingly small, so that their depth is only a fraction of the thickness of the dorsal wall of the cord. The attainment of this condition marks the point where the wall of the stomochord is continuous with the epithelium of the anterior end of the pharynx (Pl. 10. fig. 2, *St.o.*).

Nuchal Skeleton.

The nuchal skeleton is well developed in *Pt. pelsarti* and bears characters which are of diagnostic importance. It consists of cupule, body, keel, and cornua.

In *Pt. flava*, the cupule is figured by Willey as embracing the posterior end of the ventral dilatation of the stomochord. In the Abrolhos species, the anterior margin of the cupule is transversely expanded, and embraces the lateral pouches of the stomochord (Pl. 10. fig. 6, *Sk.l.*). Proximally to this, the cupule passes into the anterior part of the body. The latter, at this point, is only slightly compressed, and there is no crest projecting into the stomochord, although a slight convexity towards this structure may be noted.

In some species of the Ptychoderidæ a ventral keel is present, and at the anterior end this is separated from the body proper by a thin band of chondroid tissue. Willey, describing *Pt. flava*, states that no keel is present in that species, and that in this respect *Pt. flava* resembles *Pt. erythraea*, where the place of the keel is occupied by the large ventral cæcum of the proboscis cœlom, against which the body of the skeleton expands. Punnett both describes and figures a keel on certain of his varieties of *Pt. flava*, without referring to this noteworthy difference from Willey's description. Either Willey considered that the structure to be discussed below, which resembles the "keel" of Punnett's description, was not really the keel, or else Willey's *Pt. flava* was considerably different from Punnett's varieties of that species.

In *Pt. pelsarti* a keel-like ventral ridge is present on the nuchal skeleton. Anteriorly this is separated from the main part of the body by chondroid tissue—but it would, perhaps, be better to say that at this point the compact substance of the skeleton passes into a transverse band of chondroid tissue.

Slightly posterior to the commencement of the keel, two well-developed wings (Pl. 11. fig. 8, *Sk.'*) appear as lateral projections, and extend outwards on each side for some distance, eventually passing into the basement-membrane which underlies the nerve-layer of the proboscis neck at this point. The figures explain this better perhaps than is possible in a written description. Ventral to the wings of the skeleton the keel is compressed (fig. 8), and hollowed slightly to receive the ventral cæcum of the proboscis, which is strongly compressed, as we have seen above. The keel clasps this cæcum, its ventral processes gradually thinning out (fig. 8, *Sk.''*) and passing into

the basement-membrane, which underlies the small-celled epithelium of the so-called racemose organ.

A horizontal section taken through the neck of the proboscis in the region just described (Pl. 11. fig. 8) shows some of the characteristic features of the species.

Posterior to the region described above, the keel separates from the ventral proboscis cæcum, and at the same time loses its concavity and the clasping ventral margins (fig. 7). The lateral edges run out into chondroid tissue. Passing still further in a posterior direction, we find that the skeleton becomes more and more elongated in a lateral direction, still keeping a ventral keel, until finally this disappears and the transversely elongated skeleton diverges into the two posterior limbs—the cornua.

The cornua commence rapidly to diverge and embrace the œsophagus. Now it is characteristic of the Ptychoderidæ that the cornua of the nuchal skeleton terminate in front of the middle region of the collar, and in most species they do not pass back very far. In Punnett's varieties of *Ptychodera flava* the cornua only extend one-seventh to one-fourth the length of the collar, except in one variety, *Pt. flava*, var. *cooperi*, Punnett, where they attain such an extraordinary length that they approximate the posterior end of the collar. In *Pt. pelsarti* the cornua (fig. 10, *Sk.*') extend more than halfway down the length of the collar, and embrace the œsophagus to such an extent that near their terminations they are much nearer the mid-ventral line than the dorsal surface (fig. 10). This is quite a characteristic feature of the species. Apart from the great length of the cornua in Punnett's variety, there is but little resemblance between that form and *Pt. pelsarti*.

Chondroid Tissue of the Nuchal Skeleton.

The cartilage-like chondroid tissue, referred to at great length by Spengel in his well-known monograph, is well developed in the present species. It is impossible, however, to my mind, to speak of it apart from the skeleton—or to figure the skeleton as an isolated structure, as is sometimes attempted. There is no definite line of demarcation, in the best sections, between the chondroid tissue and the substance of the main mass of the nuchal skeleton (fig. 8, *Sk.* & *Ch.T.*).

Furthermore, the skeletal substance passes quite insensibly into the basement-membrane, and it is evident that in the nuchal skeleton we have a structure which is a local development of a tissue of wider extent. The fact that in some species of Enteropneusta, i. e. *Balanoglossus clavigerus*, there are numerous small cells scattered throughout the skeleton still further emphasises the point that the chondroid tissue is merely an extension of the substance of the skeleton.

In a transverse section, taken at about the plane of the proboscis pores, the chondroid tissue extends almost completely round the central blood-sinus

of the proboscis (Pl. 11. fig. 8, *Ch.T.*), and sometimes the canal leading to one of the proboscis pores is missing for a space, the chondroid tissue taking its place (fig. 9, *Ch.T.*).

The chondroid tissue when highly magnified is distinctly fibrous. With hæmatoxylin and eosin it often stains like the blood in the central blood-sinus. Its structure differentiates it at once. Every here and there are cavities, in which lie small fusiform nucleated cells. It is assumed by Spengel and Willey that the cells of the chondroid tissue arise chiefly from the epithelium of the dorsal cœlomic canals. This is probably the case, but the cells found enclosed in the chondroid tissue are, to my mind, part of the tissue itself, and responsible for its production.

Vascular System.

Proboscis glomerulus.—The glomerulus, like that of *Glossobalanus minutus* and *Balanoglossus australiensis*, extends over, and forms a cap to, the pericardium and the stomochord (Pl. 10. fig. 2). Posterior to the end of the stomochord, the glomerulus becomes restricted to two lateral masses lying one on either side of the central complex of the proboscis (fig. 4, *rad.glom.*). The cells of the splanchnotheca are easily recognised, covering the glomerulus distally (fig. 4, *Spl.*). There is little to add in the way of details. The general arrangement of the blood-spaces is similar to that already described in other Ptychoderidæ. The efferent proboscis vessels (figs. 5 & 8, *Eff.V.*) cannot be recognised anteriorly to the proximal end of the glomerulus. They are not only in connection with each other by blood-spaces situated in the chondroid tissue, between the body and keel of the proboscis skeleton, but they enter into communication with the capillary network of the proboscis. This condition was first described by Hill in *Balanoglossus australiensis*. It is probably to be met with in other species of the Ptychoderidæ.

Pericardium.

The pericardium (Pl. 10. figs. 2 & 4, Pl. 11. figs. 5 & 9, *Per.*) has the same essential structure as in the other described species of *Ptychodera*. It extends anteriorly just as far as the stomochord. Dorsally it is connected to the integument for some distance, thus forming a dorsal hollow septum in the proboscis (fig. 5). This contact with the integument of the proboscis ends at about the plane of the lateral cæca of the stomochord. The ventral wall of the heart-bladder is convex, owing to the space underlying it being occupied by the central blood-sinus (figs. 2, 4, 5, & 8, *C.b.s.*). There is, however, no infolding of the pericardium as in *Balanoglossus australiensis*. The cavity of the pericardium is almost filled with cellular tissue which extends right to the distal end of this organ. There is practically no difference in the appearance of this cellular tissue throughout the pericardium. The same transverse

fibres (Pl. 11. fig. 9) which have been noticed by previous observers in other species of Enteropneusta occur at the posterior end of the organ.

Nervous System.

As is well known the nervous system of the Enteropneusta consists of a nerve-fibre layer present in relation with ectodermal epithelium. In certain places this layer is very much thickened, giving rise to so-called nerve-trunks or nerve-cords. The general structure of the nervous system of *Pt. pelsarti* agrees with that of described species, and so reference will only be made here to points of systematic importance.

The most important nerve-trunk is the Collar Nerve-Cord. This cord, in the genus *Ptychodera*, is frequently a true medullary tube (*Pt. flava*) possessing a central canal opening to the exterior at both anterior and posterior ends. In some cases only a few cavities are to be seen (*Glossobalanus minuta*, *Balanoglossus australiensis*, etc.). In the species now being described there is a well-developed continuous canal (Pl. 10. fig. 2, *Can.N.C.*) with anterior and posterior neuropores (fig. 2, *Ant.N.P.* and *Post.N.P.*). This appears to be characteristic of all members of the genus *Ptychodera*, although Punnet found a marked tendency to occlusion of the canal in many specimens of his varieties of *Pt. flava*. There is no tendency towards occlusion in any of the specimens of *Pt. pelsarti* examined.

In transverse section the cord is everywhere much broader than deep (dorso-ventral measurement) (Pl. 11. fig. 10).

The nerve-substance is almost confined to the ventral side of the tube (fig. 2, *D.N.C.*). It is much more thin laterally, and dorsally can only just be recognised. In fact, the dorsal and ventral walls of the collar nerve-cord are entirely different. The cells of the dorsal wall are very delicate, and not nearly so numerous as the cells of the ventral wall. The ventral wall agrees much more with the external epithelial layer of the proboscis, particularly with that of the anterior neuropore region. It is true that gland-cells are not so numerous, but they are present in very considerable numbers, and quantities of mucus may be found in the lumen of the nerve-trunk. There are very few gland-cells amidst the cells of the dorsal wall, except in the posterior region of the collar, where they become slightly more numerous. There are no traces of giant ganglion cells.

As in other species of *Ptychodera*, the collar nerve-trunk is united with the epidermis at intervals by unpaired dorsal roots (fig. 2, *D.R.*¹, *D.R.*²). These are few in number, three roots being most common. The anterior root arises in front of the middle point of the cord, almost in the same plane as the opening of the stomochord into the throat-cavity (fig. 2). This agrees with Hill's description of *Balanoglossus australiensis*, and is contrary to Spengel. The roots arise as hollow diverticula from the medullary tube and run

obliquely backwards. A lumen may be traced for quite a distance—at least, in the most anterior roots. The histological structure is practically the same as that of the dorsal wall of the nerve-cord.

Collar Epidermis.

The collar epidermis is divisible, as in other species of *Ptychodera*, into five zones (Pl. 10. fig. 2). The extent of these has been previously noticed. It will suffice here to mention that the second, third, and fourth zones are somewhat similarly constituted, and in section stain darkly with hæmatoxylin owing to the numerous gland-cells present. The fourth zone of the collar is, however, the most markedly glandular region of the animal's epidermis and stains very intensely with hæmatoxylin. The fifth region is very free from dark staining cells.

Collar Cælom.

The cavity in the anterior half of the collar is reduced, a considerable amount of connective tissue being present between the outer epidermal muscle-layers and those underlying the wall of the alimentary tract (fig. 2, *C.tis.*). Behind the anterior region there are numerous transverse muscle-fibres arranged in radial bundles (Pl. 11. fig. 10, *R.mus.*), and the cavity—collar cælom—is thus split up somewhat.

A well-developed dorsal septum is present, in the specimen examined, posterior to the second root of the collar nerve-cord (fig. 10, *D.Sept.*). On the ventral side of the collar a longitudinal space is present, into which project folds with vessels belonging to the ventral vascular plexus (fig. 10, *V.plex.*). No ventral septum appears to be present.

Collar Canals.

The collar canals have the same characters as those of many other described species of the Ptychoderidæ, i. e. *Pt. flava*, *Glossobalanus minuta*, *Balanoglossus australiensis*, etc.

Branchio-genital Region.

Reference need only be made to a few points here, for the general structure is in agreement with that of the other known species of *Ptychodera*. The gonads extend forwards in the genital pleura up to the most anterior gill-clefts. The pleura are well developed and arise somewhat deeply, but certainly not so far ventrally as is the case in some other species of *Ptychodera*. There is, moreover, a very striking difference between transverse sections of *Pt. flava* (and apparently its varieties) and *Pt. pelsarti*, the sections being taken through the branchio-genital region in each case. The difference lies in the relative area of the branchial and œsophageal divisions of the pharynx. In *Pt. flava* the branchial region predominates over the

oesophageal. In *Pt. bahamensis* both divisions are nearly equal in area. In *Pt. erythraea* the branchial region is the smaller of the two, and this is the condition in *Ptychodera pelsarti*. The two cavities are not separated quite as distinctly in the latter species as in the others named here. There is no great constriction separating the two regions, which are consequently open to each other by a rather wide channel. The line of demarcation between the bases of the gills and the oesophageal epithelium is, as usual, marked by longitudinal parabranial ridges. They consist of epithelial cells which are twice or more than twice as deep as the cells lining the rest of the oesophageal division of the pharynx.

The lateral septa of the genital pleura (Pl. 11. fig. 11) bearing blood-vessels, and connecting the gonads, arise as described by Willey in *Pt. flava*. They are co-extensive with the genital pleura, and arise from the basement-membrane close to the base of the gill-clefts. They are inserted into the same basement-membrane near the free margin of the pleura. Behind the pharynx there still seems to be some doubt as to the point of origin of the lateral septa—Punnett and Spengel disagree with Willey. It has not been possible to settle this question definitely from the slides at present at my disposal.

The gonads, as in *Pt. flava*, are met so far anteriorly that they occur in the same transverse sections as the collar canals. In other respects the reproductive organs agree very closely with those of the other species of the genus *Ptychodera*.

Posterior to the gill-region the much reduced genital pleura encroach on the hepatic region.

Hepatic Region.

The Hepatic Region is similar in structure to that of other species of the genus.

The epithelial wall of the alimentary canal is thrown into folds of considerable irregularity, so that in transverse sections one meets "islands" of "wall" on all sides.

Two longitudinal grooves are present dorso-laterally, as in *B. australiensis*, *Pt. flava*, and *Gl. hedleyi*.

The genital pleura can be traced into the hepatic region as very low elevations just above the longitudinal grooves, a condition similar to that described by Hill for *B. australiensis*.

Caudal Region.

Since Willey invented the term Pygochord for the ventral structure first described by Spengel as a "Kielförmiger Fortsatz" of the intestinal epithelium, some little discussion has arisen concerning this feature. Willey

states that it commences as "a simple thickening of the ventral wall of the hind gut, which is soon drawn out into a flattened band with dilated distal (ventral) border."

In *Pt. pelsarti* a pygochord is present, and consists, for the greater part, of a band of tissue running from below the gut-epithelium in the mid-ventral line to the basement-membrane of the integument. The tissue is cellular with oval nuclei, and on each side of it is basement-membrane. The structure certainly seems too delicate to be of much service as a support, although it may possibly serve as a kind of mesentery. There is no evidence in the species examined either in favour of or against Punnett's ingenious suggestion that the pygochord may be the remains of a ventral siphon now vestigial.

SUMMARY.

It will be advisable perhaps to add, in the form of a summary, a short diagnosis of the characters of the species *Ptychodera pelsarti*.

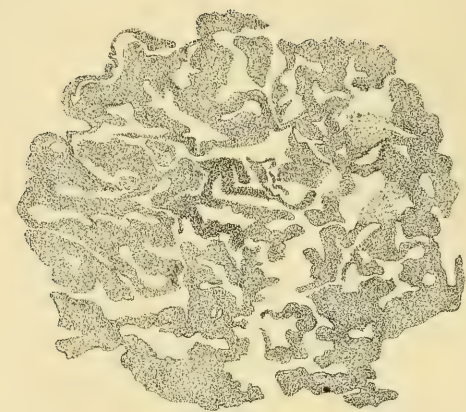
PTYCHODERA PELSARTI, n. sp.—Moderately large form, average size of *preserved* specimens 50–60 mm. (considerable contraction had taken place). Proboscis cavity with longitudinal muscles gathered into distinct radially arranged bundles. Neck of proboscis with a distinct well-developed but unlobulated "racemose" organ. Ventral proboscis, cæcum, and "racemose" organ compressed laterally. Cornua of nuchal skeleton very long and reaching posterior half of collar, body of skeleton with characteristic shape. Two proboscis pores. Stomochord with well-developed lateral pouches. Œsophageal region of pharynx predominates over the branchial. Collar nerve-cord with continuous lumen and usually with three dorsal roots. Locality: Pelsart Island, Abrolhos Islands, West Coast of Australia.

EXPLANATION OF PLATES 10 & 11.

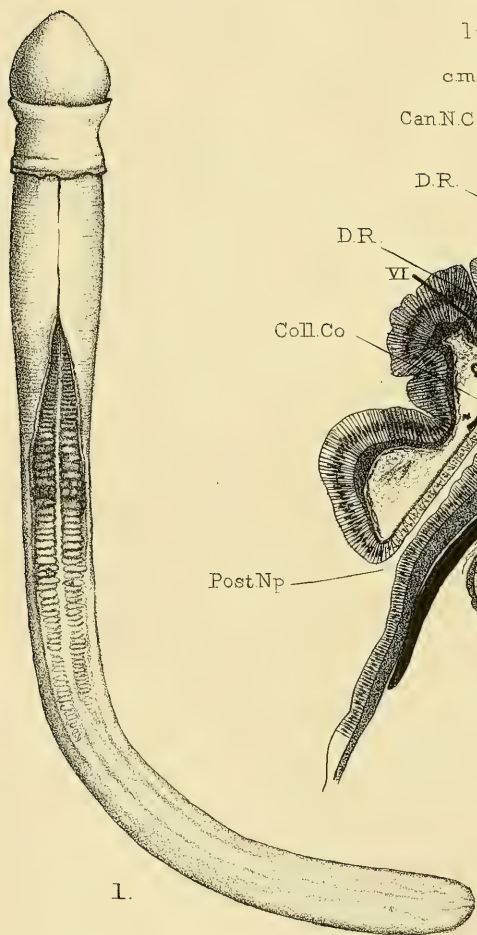
Reference letters.

(Figures 1–4, 6 are on Plate 10; figures 5, 7–12 on Plate 11.)

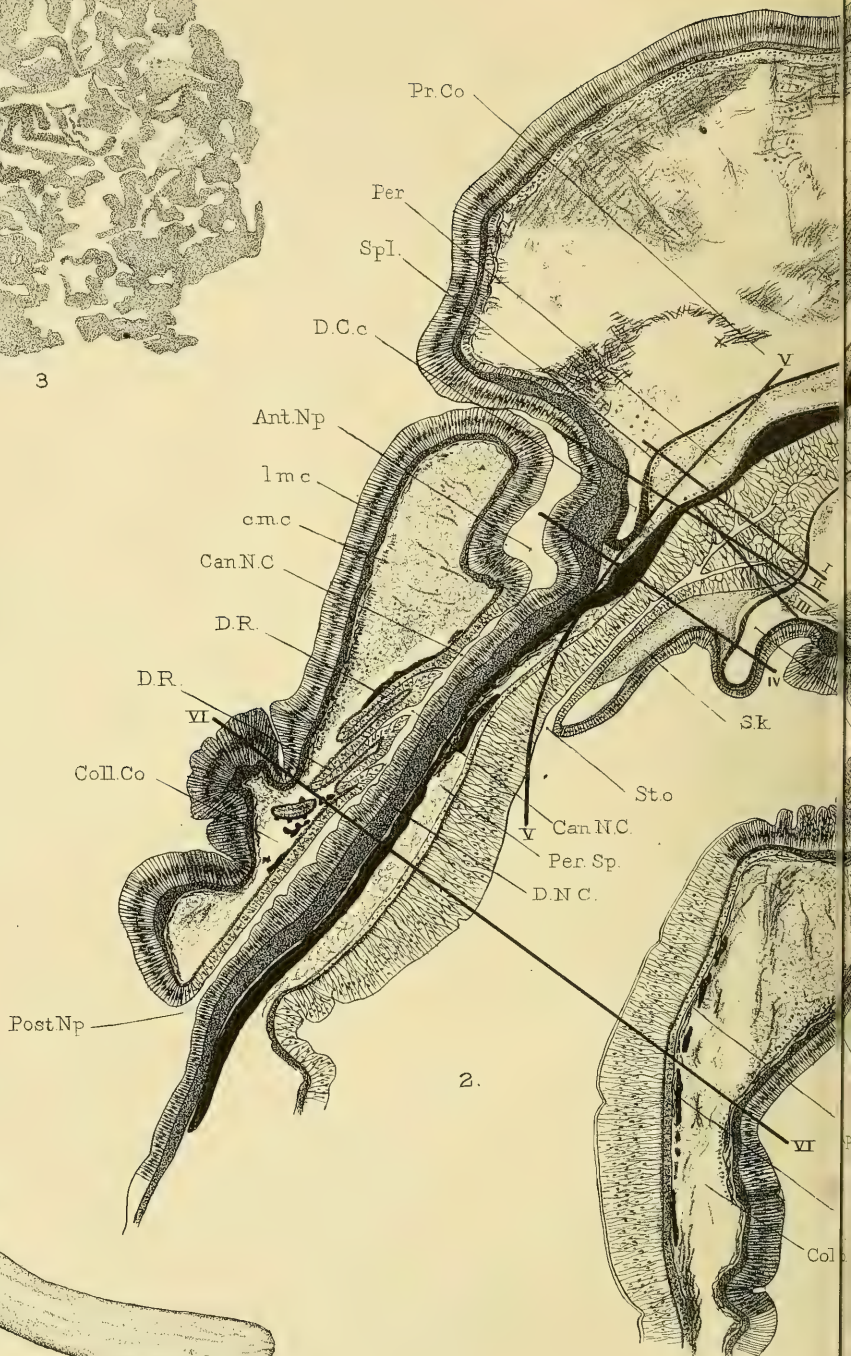
- Ant.Np.* Anterior neuropore. Fig. 2.
- Br.* Branchial bar. Fig. 11.
- Br.c.* Branchial region of alimentary canal. Fig. 11.
- C.b.s.* Central blood-sinus of proboscis. Figs. 2, 4, 5, 8, & 9.
- c.m.c.* Circ. muscle-fibres of collar. Fig. 2.
- C.tis.* Connective tissue of collar. Figs. 2 & 10.
- Can.N.C.* Canal of dorsal nerve-cord. Figs. 2 & 10.
- Ch.T.* Chondroid tissue. Figs. 7, 8, & 9.
- Coll.Co.* Collar cœlom. Figs. 2 & 10.
- D.C.c.* Dorsal cœlomic canal of proboscis. Figs. 2, 5, & 9.
- D.N.C.* Dorsal nerve-cord. Figs. 2 & 10.



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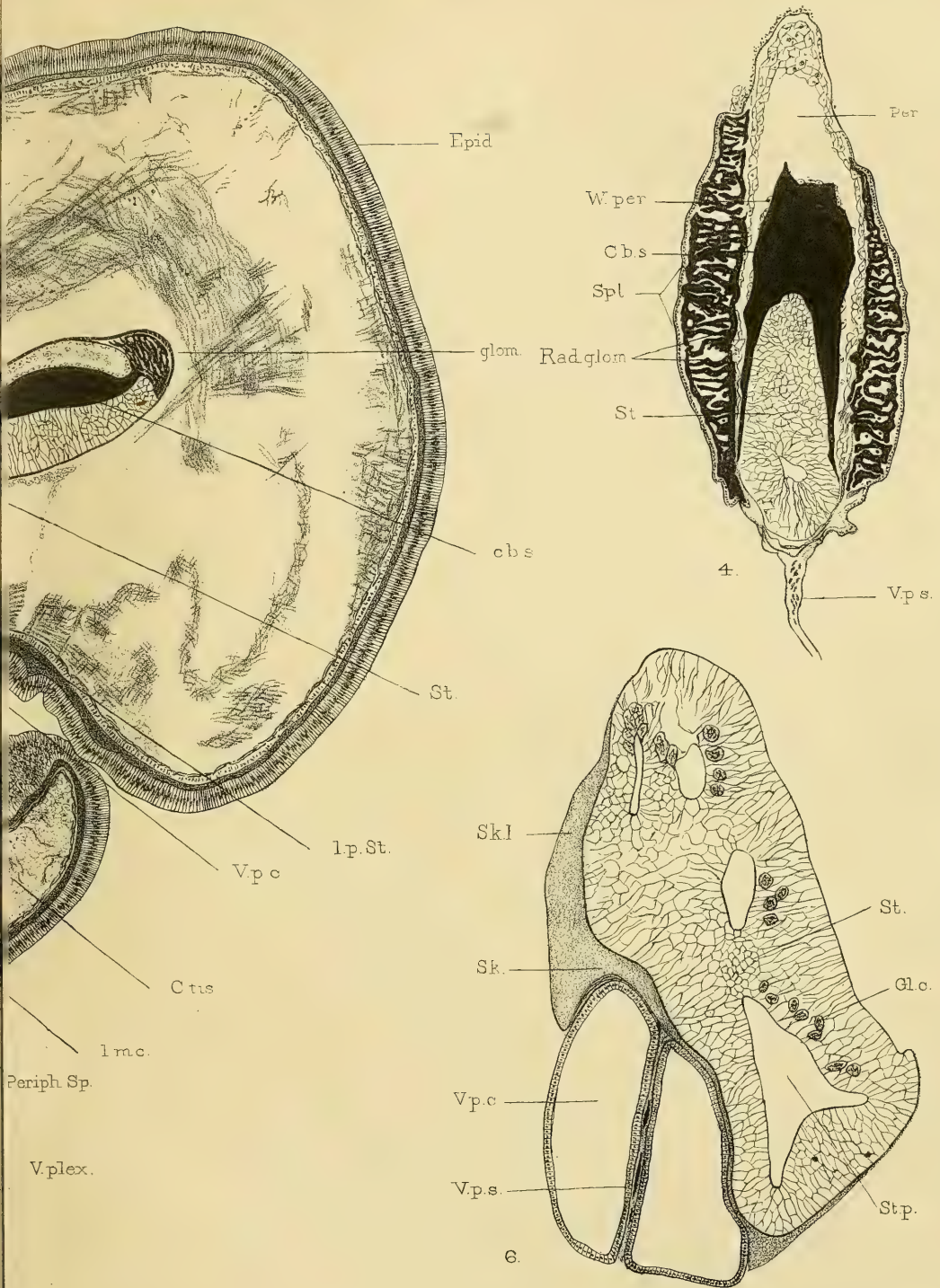
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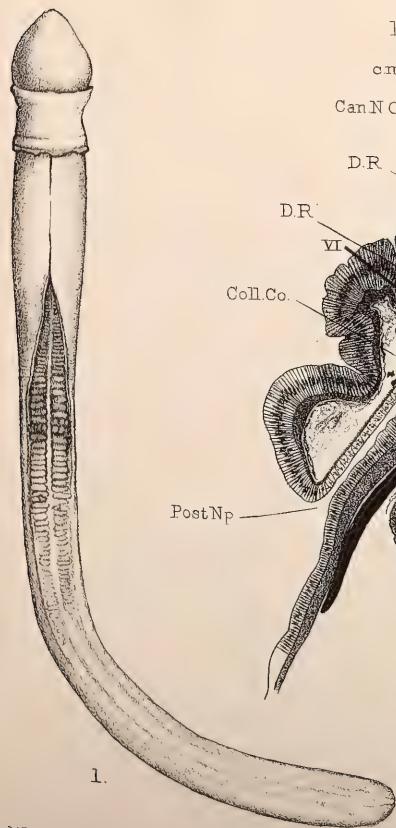
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C. Hodges & Son. Lith. Lon.

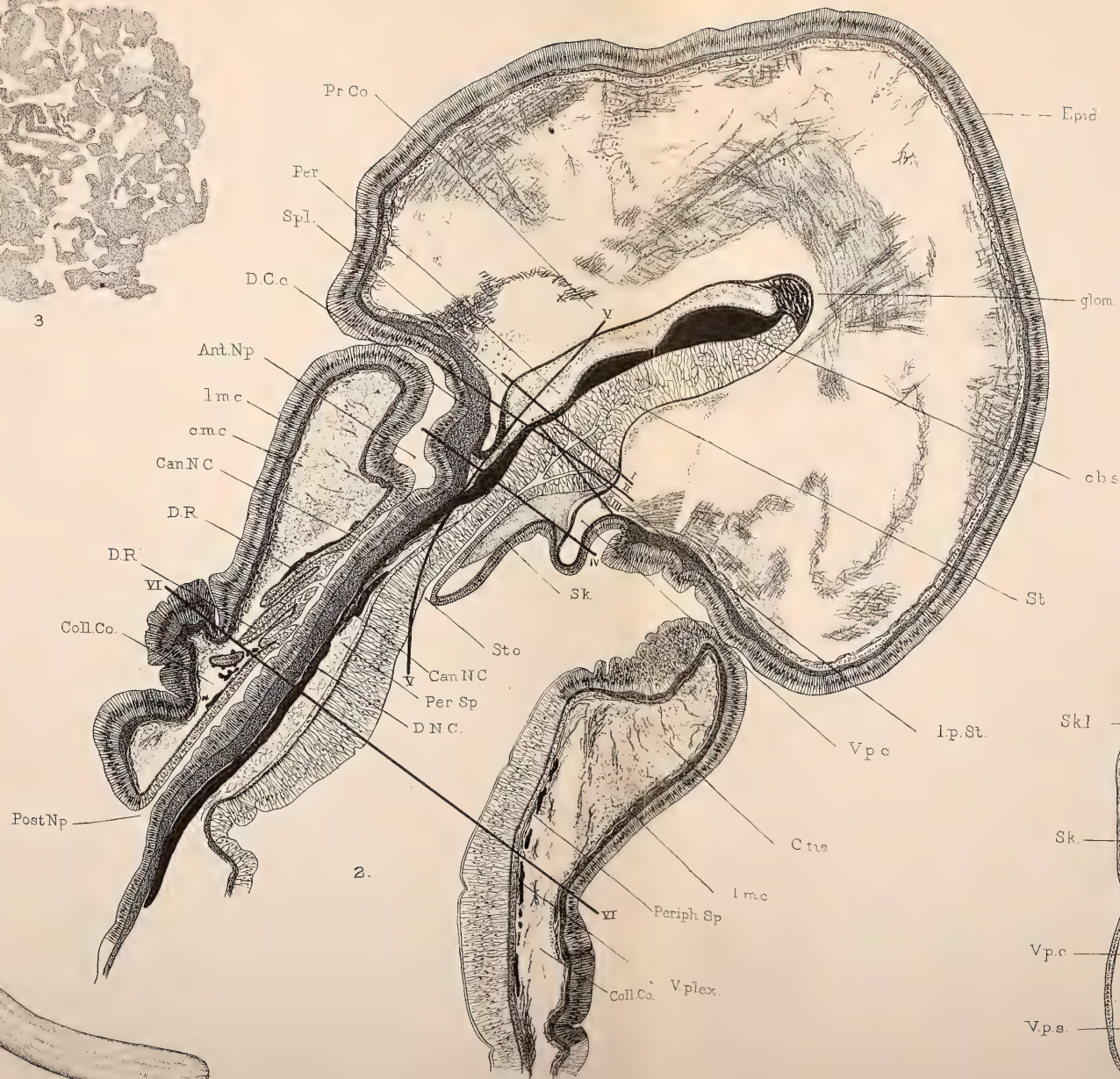


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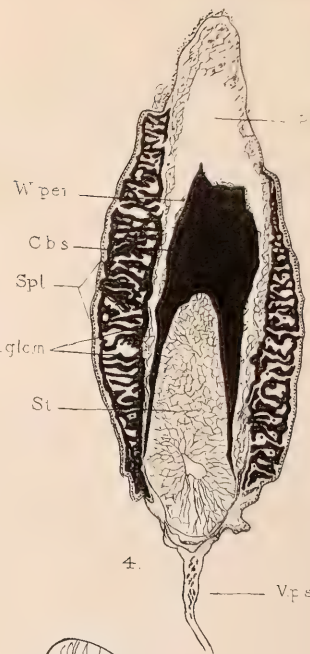


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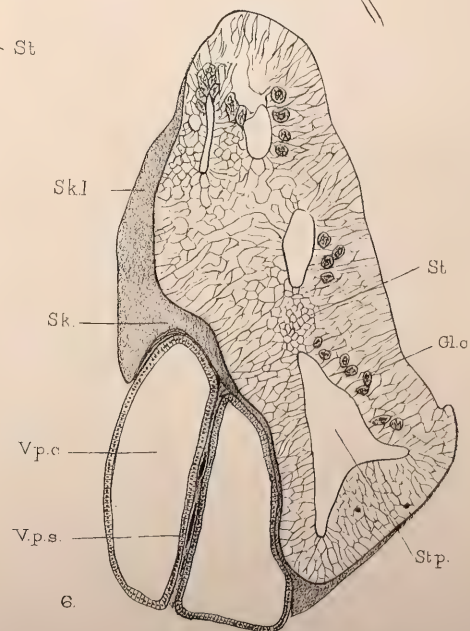
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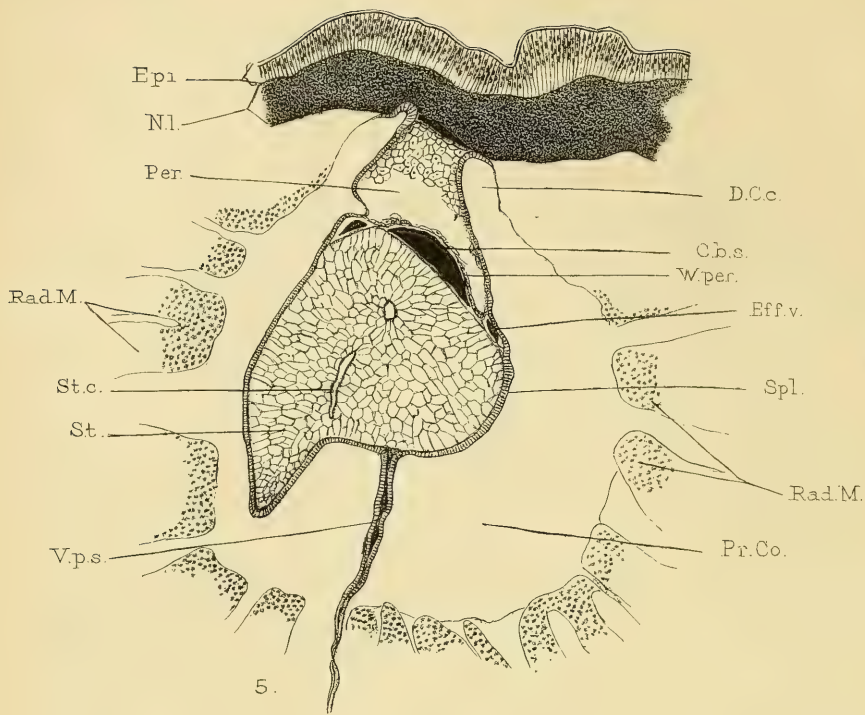
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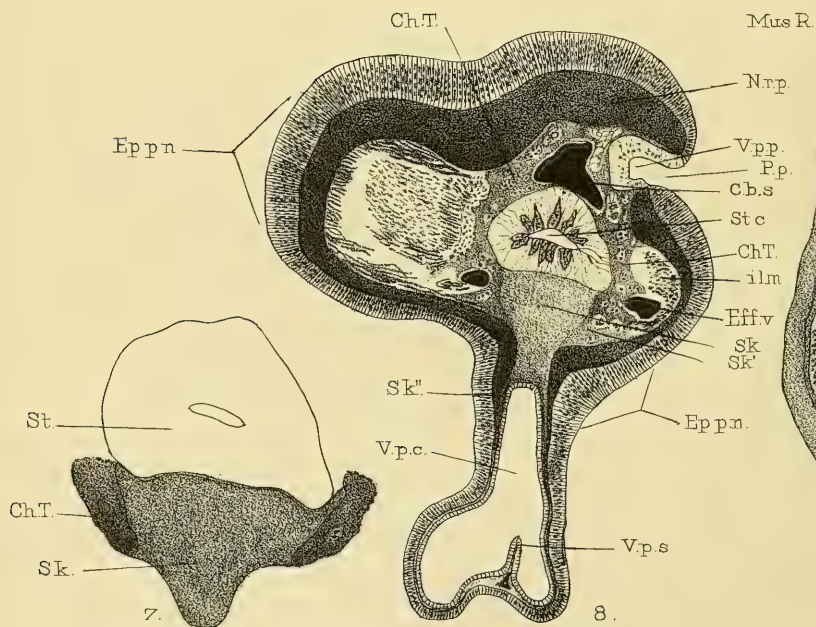
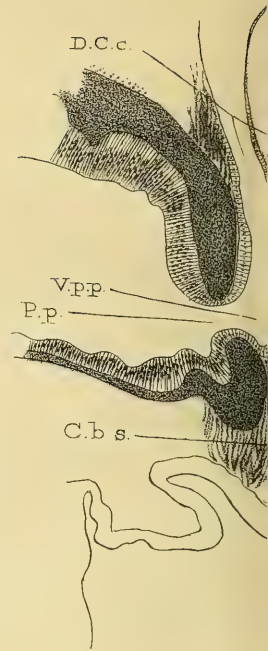
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PTYCHODEPA PELSARTI



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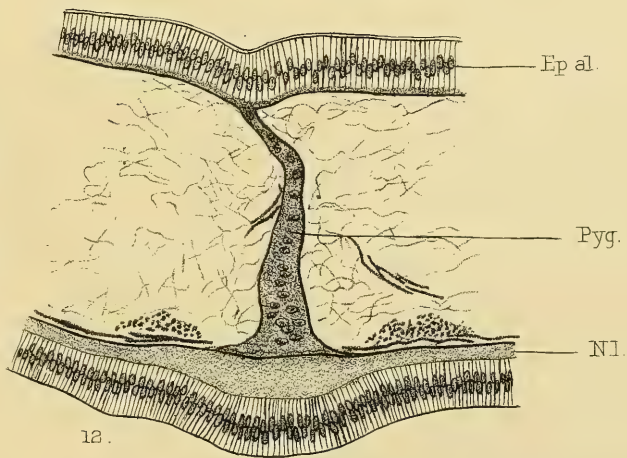
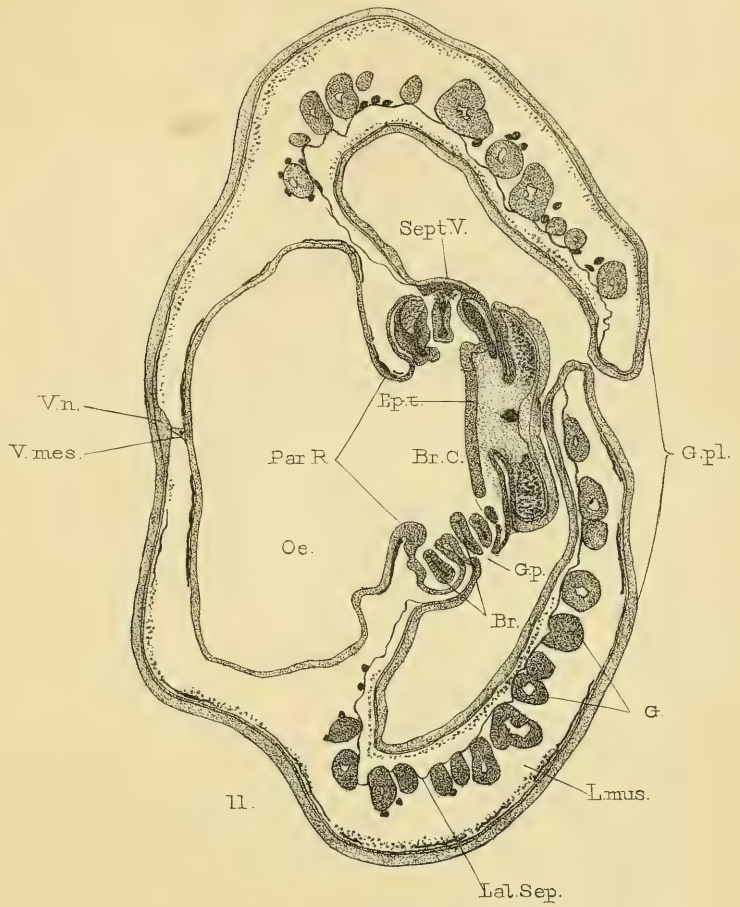
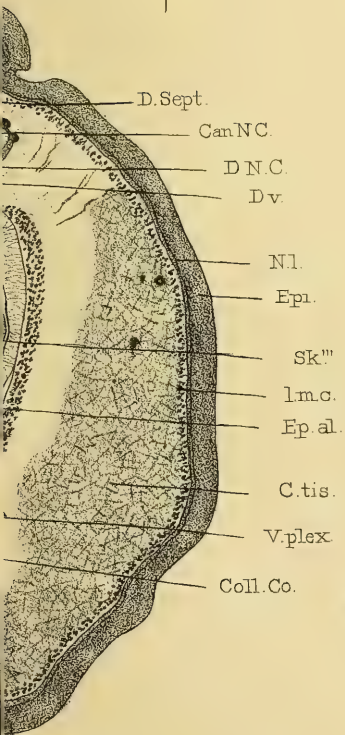
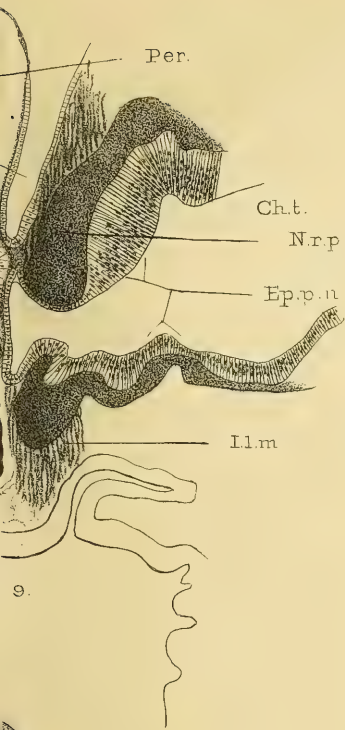
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W.J.D. del.



C.Hodges & Son.Lith.Lon.

- D.R.'* } Dorsal roots of nerve-cord. Fig. 2.
D.R'' }
D.Sept. Dorsal septum of collar. Fig. 10.
D.v. Dorsal vessel of collar. Figs. 5 & 8.
Eff.v. Efferent vessels of proboscis. Figs. 5 & 8.
Ep.al. Epithelium of alimentary canal. Figs. 10 & 12.
Ep.p.n. Epithelium of neck of proboscis. Figs. 8 & 9.
Epi. Epithelium external to nerve-fibre layer. Figs. 5, 10, & 12.
Epid. Epidermis of proboscis. Fig. 2.
G. Gonads. Fig. 11.
G.pl. Genital pleura. Fig. 11.
Gl.c. Gland-cells. Fig. 6.
glom. Glomerulus. Fig. 2.
G.p. Branchiopore.
i.l.m. Inner longitudinal muscles of collar. Figs. 8 & 9.
l.m.c. Longitudinal muscles of collar. Figs. 2 & 10.
L.mus. Longitudinal muscles of branchio-genital region. Fig. 11.
l.p.St. Lateral pouch of stomochord. Fig. 2.
Lat.Sep. Lateral septum.
Mus.R. Radial muscle collar. Fig. 10.
N.l. Nerve-fibre layer of epidermis. Figs. 5, 10, & 12.
N.r.p. Nerve-ring of proboscis neck. Figs. 8 & 9.
Oe. Oesophageal division of alimentary canal. Fig. 11.
P.p. Proboscis pore. Figs. 8 & 9.
Par.R. Parabranial ridges. Fig. 11.
Per. Pericardium. Figs. 2, 4, 5, 9, & 12.
Per.Sp. Perihæmal space. Fig. 2.
Perip.Sp. Peripharyngeal space. Fig. 2.
Post.Np. Posterior neuropore. Fig. 2.
Pr.Co. Proboscis cœlom. Figs. 2 & 5.
Pyg. Pygochord. Fig. 12.
rad.glom. Radial portions of glomerulus. Fig. 4.
Rad.M. Longitudinal muscles of proboscis in radial bundles. Fig. 3.
Sept.V. Septal vessel of gills. Fig. 11.
Sk. Nuchal skeleton. Figs. 2, 6, 7, & 8.
Sk.' Lateral wing of nuchal skeleton. Fig. 8.
Sk'' Projections of skeleton clasping ventral proboscis cœcum. Fig. 8.
Sk''' Cornua of nuchal skeleton. Fig. 10.
Sk.l. Lateral projection of anterior part of skeleton. Fig. 6.
Spl. Splanchnotheca. Figs. 2, 4, & 5.
St. Stomochord. Figs. 2, 4, 5, 6, & 7.
St.c. Cavity of stomochord. Figs. 5 & 8.
St.O. Opening of stomochord to pharynx. Fig. 2.
St.p. Lateral pouches of stomochord. Fig. 6.
V.mes. Ventral mesentery. Fig. 11.
V.n. Ventral nerve-thickening. Fig. 11.
V.p.c. Ventral proboscis cœlom.—Cavity of "racemose organ." Figs. 2, 6, & 8.
V.plex. Ventral vascular plexus of collar. Figs. 2 & 10.
V.p.p. Proboscis pore vesicle. Figs. 8 & 9.
V.p.s. Ventral proboscis septum. Figs. 4, 5, 6, & 8.
W.per. Wall of pericardium. Figs. 4 & 5.

- Fig. 1. *Ptychodera pelsarti*, n. sp. $\times 2$.
- Fig. 2. Sagittal section through proboscis and collar of *Pt. pelsarti*. The lines marked I, II, III, IV, V, and VI indicate the planes of the sections illustrated in the following figures. $\times 40$.
- Fig. 3. Transverse section through tip of glomerulus distal to stomochord. $\times 60$.
- Fig. 4. T. S. central complex of proboscis. $\times 54$.
- Fig. 5. T. S. stomochord, pericardium, and portions of proboscis integument. Plane of section, line I in fig. 2. $\times 50$.
- Fig. 6. T. S. stomochord, nuchal skeleton, and "racemose" organ. Plane of section, line III in fig. 2. $\times 100$.
- Fig. 7. T. S. stomochord and skeleton. $\times 80$.
- Fig. 8. T. S. proboscis neck. Plane of section, line IV in fig. 2. $\times 54$.
- Fig. 9. Horizontal section through plane indicated by curved line V in fig. 2, and showing condition of proboscis pores and dorsal coelomic canals on both sides. $\times 50$.
- Fig. 10. T. S. collar. Plane of section, line VI in fig. 2. $\times 20$.
- Fig. 11. T. S. through branchio-genital region. $\times 50$.
- Fig. 12. Ventral portion of transverse section through caudal region, showing pygochord. $\times 140$.
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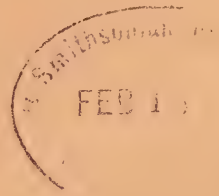
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Larval and Post-Larval Stages of *Jasus lalandii* (Milne Edw.), Ortmann.

By J. D. F. GILCHRIST, M.A., D.Sc., Ph.D., F.L.S.

[PLATES 12-17, and 12 Text-figures.]

[Read 2nd March, 1916.]



IN the Journal of the Linnean Society, Zoology, vol. xxxii. October (1913), p. 225, I described the newly-hatched larva of *Jasus lalandii*. Since then sufficient material has been procured to give a fairly complete account of later stages. This includes the immediately succeeding stage (1·7 mm. in length), numerous specimens of which were got by rearing from the egg and by tow-netting in Table Bay, a much less numerous series procured further from the shore (from 3·8 to 37 mm. in length), and, finally, a number of specimens of the "puerulus" stage (from 22 to 26 mm.), and of succeeding stages in which the cuticle becomes calcified.

That all these are stages of *Jasus lalandii* seems probable from their general resemblance, and from a comparison with phyllosomas found at other places on the South African coast. The evidence from locality is also particularly trustworthy, owing to the distribution of the Cape crawfish and other South African Loricata. *Jasus lalandii* is abundant on the west coast from Cape Point northwards, but to the east of this it is very scarce, and has not been found on the east coast north of Port Elizabeth. On the south coast a *Palinurus* has been found, but it is not abundant. On the east coast a *Panulirus* is fairly abundant, and *Scyllarides* is common in Natal waters. The phyllosomas referred to *Jasus* have all been found on the west coast. Three other kinds have been procured from the south and east coasts: one, which grows to a very large size, is, on the evidence of its flat tentacles, referable to *Scyllarides*, the other two probably to *Palinurus* and *Panulirus*. The puerulus stages referred to *Jasus* have all been found in Table Bay; two other kinds, obviously different, have been found on the east and south coasts and are probably referable to the other South African Loricata mentioned—one with a pair of ventral spines to *Palinurus*, and the other with long antennular flagella to *Panulirus*.

In the following account a more detailed description of the first or "naupliosoma" stage, for purposes of comparison, is given; a typical phyllosoma stage of 1·7 mm. is described; succeeding stages of 3·8, 24, 26, 33, 35, and 37 mm. are then described in such detail as seems necessary, and, lastly, some points, which seem to be of significance, are noted in the "puerulus" stage.

THE NAUPLIOSOMA.

For comparison with later stages, further details with figures, of the appendages, may be given. (I may here note incidentally that the name suggested as convenient to denote this stage was not intended to suggest any connexion with the nauplius stage, which, as stated, has presumably been passed long before in the development of the embryo. The name was given on account of the apparent resemblance of this stage, when seen in the living condition, to a nauplius; it was not intended to suggest any direct relation to the nauplius stage, and, in so far as it does so, is inappropriate.)

The *antennules* (Pl. 13. fig. 1) are as described, and it may be added that, in addition to the stout terminal spines under the cuticle, the long filamentous processes, described in the next stage, can also be made out, though not clearly, as they are coiled up under the cuticle.

The *antennæ* (Pl. 13. fig. 2) are also as described. The protuberances at their bases seem, on further examination, to be due to the presence of the antennal gland.

The *mandibles* (Pl. 13. fig. 3), as viewed from below, are short limbs, bent inwards at their tips, which end in a tridentate spine. When they are dissected out and viewed from the posterior or anterior aspect, the spine is seen to be the first of a series, which extends inwards towards the body and ends in a separate group of small stout spines. The whole is covered by cuticle, and as the general arrangement of these spines does not differ essentially from that in the largest phyllosomas, they will be described there in more detail.

The *first* (Pl. 13. fig. 4) and *second maxillæ* (fig. 5) are as described.

The rudimentary *first maxillipede* (fig. 6) does not appear to have a cuticle covering its single spine at this stage.

The *second maxillipede* (fig. 7) consists of five distinct segments: the first is short and is followed by a long one; the third is again short, the fourth is longer, and the fifth is small and terminated by about four spines under the cuticle.

The *third maxillipede* (fig. 8) has also five distinct segments, the first short, the second very long, and, at its proximal end, coiled or folded on itself, there being about two such distinct coils or folds; the third segment is short, straight and not coiled, as are also the fourth and fifth, the last having some spines under the cuticle. The whole appendage is bent in the form of an irregular S, and, in its normal position lies, compactly folded up, under the succeeding appendages, which are arched forward over the ventral side of the body.

The *first pereopod* (fig. 9) has the first two segments broad, comparatively short, and well provided with muscles; the strong spine, so well developed in the phyllosoma on the first segment, does not appear. In the second the

muscles, destined to control the active movement of the exopodite in the next stage, are specially marked. The endopodite is much coiled on itself, so that it is not very much longer than the exopodite. Such coiling occurs at the proximal end of the first segment, where the limb is completely bent on itself, the remainder of its length being quite straight. The second segment of the endopodite is relatively short and straight; the third is the most coiled, there being one or two complete coils, gradually passing into mere undulations, and eventually into the straight distal part of the segment. The last segment is short and straight. The exopodite is not shortened by such coiling of the limb under the cuticle; it is already divided into segments more or less distinctly, but there are no swimming setæ.

The *second pereopod* (fig. 10) is very similar to the first.

The *third pereopod* (fig. 11) has the first two segments well developed and somewhat similar to those of the preceding appendages; the second, however, is rather slender, slightly coiled, and not marked off clearly from the succeeding. It also has the rudiment of an exopodite at its distal extremity. The first segment of the endopodite is long, somewhat slender, and coiled at its proximal extremity, the second is short and straight, but the third is long and very much coiled at its proximal end for a little over half its length.

The *fourth pereopod* is represented by a slight swelling between the base of the third and the commencement of the abdominal region. In *Palinurus vulgaris* the fourth and fifth pereopods are present on hatching.

PHYLLOSOMA OF 1.7 MM. [Fig. 12] Pl. 14.

The stage succeeding the naupliosoma is the characteristic phyllosoma, with transparent body, without the locomotory setæ of the antennæ, and provided with locomotory setæ on the exopodites of the walking-legs. The spines and setæ covered by cuticle in the last stages are now exposed, and the appendages, which were formerly coiled up under the cuticle, now become straight and about double their former length. Though this transformation is thus effected at a single ecdysis, there is no stage at which the larva is not provided with active swimming organs, for, as was observed, the cuticle with the swimming setæ of the antennæ is shed some time after that of the other appendages, so that by the time these were lost those of the exopodites of the pereopods were in full activity.

The body is now transparent, being devoid of yolk-granules, though some may be seen in the intestine in the abdominal region. There are also present the characteristic red pigment spots seen in the naupliosoma, and present even in the embryo before hatching.

On the under side of the body a number of closely-set small projections were seen under the microscope. These cover the whole of the ventral side of the thorax, from the third maxillipedes to the beginning of the abdominal

region, but do not extend on to the bases of the walking-legs. They consist of minute dome-shaped cuticular elevations, at the apex of each of which there is a fine hair-like process about double the length of the basal portion. They occur, but more sparsely, on the ventral surface of the head region from the base of the antennæ backwards. Such fine (sensory?) setæ do not seem to have been observed on any other phyllosomas.

The diverticula of the liver can be readily seen in the transparent thorax. There are three on each side, a long one running forward on each side of the oesophagus almost to the antennal gland, a much shorter one projecting backwards, and a large trilobed lateral one. The condition, however, is not different from that in the naupliosoma stage, in which the liver can be easily seen in suitably stained specimens.

The segmentation of the body can be made out very clearly in some specimens. It consists of one distinct segment in the thoracic region—namely, the second thoracic, to which the second maxillipedes belong. Four segments can be clearly distinguished in the abdominal region in some specimens.

The eyes stand more out from the body, the peduncles being straighter, more elongate, and with their bases somewhat nearer each other.

The *antennules* (Pl. 13. fig. 13) present a marked difference from those of the naupliosoma. This is chiefly in the appearance of three long filamentous projections. They do not project forward in the same axis as the antennæ, but are, somewhat abruptly, curved downwards. The other shorter, but similar filaments were seen at their bases. They are not of the same appearance as the ordinary spines, two of which also occur at the extremity of the antennule. They were not seen in any of the phyllosomas of a larger size, but may occur there also, as they are very readily broken off. It may be suggested that they are of a sensory nature, especially as in stained specimens a group of what appeared to be nerve-cells occurs near their bases. Near the distal part of the antennule is a strong spine, and a similar one occurs a short distance behind it. There are, in some specimens, slight traces of a single division in the antennule.

The *antennæ* (fig. 14) have also changed considerably, chiefly in the absence of the long swimming setæ.

In a very few, apparently just after ecdysis, the exopodite still retains the indentations on its posterior border at the points of insertion of the setæ, but in most these are absent. The endopodite shows a marked advance. It is now longer than the exopodite, a division appears forming a proximal section, about one-fourth of its length. This is followed by a second section, terminated by two or three spines, and, lastly, follow the rudiments of the flagellum, about a third of the endopodite in length and already provided with small setæ. It may be noted that the endopodite and exopodite have apparently changed positions (*cf.* fig. 2), and at first it appeared as if the

flagellate branch was the exopodite, but this was clearly seen not to be the case, as in some specimens the non-flagellate branch still possessed the indentations of the swimming setæ. A certain amount of torsion therefore takes place in the antenna when it comes to take up a more anteriorly directed position in the phyllosoma.

The *mandible* (fig. 15, *md.*) now shows more clearly the outer tridentate spine, followed by a ridge of spines passing inward, and separated by an interval from a raised portion provided with small short spines. This arrangement does not seem to differ from that in the larger phyllosomas.

The *first maxilla* (fig. 15, *mx. 1*) consists of a short, stout, basal part, inserted immediately behind the base of the mandible. Its two short branches are each provided with two long, stout, and curved setæ, on which are secondary setæ, giving them a plumose appearance. In shed cuticles the cleft between the two branches is seen to be much deeper than appears in the complete animal, and a basal part can hardly be recognised. They are commonly regarded as two segments of the protopodite.

The *second maxilla* (fig. 15, *mx. 2*) is about .11 mm. in length, blade-like, and usually shows no division. It is attached to the body by a relatively narrow base, but soon broadens out into a flat expansion, the posterior border of which is straighter than the anterior, which is provided with a single spine about half the diameter of the blade, and situated at about the middle of its length. The appendage ends in a knob-like projection, provided with four very long plumose spines, about double the length of the appendage. This little knob is of interest, as it is destined to become the scaphognathite. In some specimens it is clearly defined by a constriction at its base.

The *first maxillipede* (fig. 15, *m.xp. 1*) is very small, and consists of a little hillock-like projection about .006 mm. in diameter and height. It has a long spine projecting from its apex, as in the naupliosoma stage, and, in fact, has not apparently altered. It is to be noted that it is here well separated from the base of the second maxilla, for, when it reappears after an apparent absence in the next stage, it occupies a different position.

The *second maxillipede* (Pl. 13, fig. 16) consists of five distinct segments. The first is short, the second about four times its length, the third equal to it, the fourth slightly longer and somewhat larger than the last. There are no spines on the first and third, but on the second there is a well-marked one, about the middle of its length. At the distal extremity of the fourth there are five long spines, each provided with spinules on its inner side. The last segment is terminated by a long curved spine devoid of spinules. At its base are four small spines. The whole appendage reaches to about the anterior third of the head region.

The *third maxillipede* (fig. 17) consists of six distinct segments, the first short and provided with a long broad spine, directed downwards and inwards. The second segment is long, and has two or three spines at its distal end, but

no trace of an exopodite. The third is slightly longer, the fourth short and terminated by three or four spines. The fifth is long, and has six spines on its distal half, the first near the middle, the second small and serrate. The third to sixth are long and differ from other spines noted in being recurved at their tips, which are provided with retrorse spinules, so that when the last joint is bent backwards between them, in the manner of a subchela, they form a most effective grasping and retaining organ. The end of this segment is provided with four long spines with antrorse serrations. The last segment is short and ends in a long spine, at the base of which are two long spines, all antrorsely serrated. The whole appendage may extend beyond the tips of the antennæ.

The *first pereopod* (fig. 18) has a stout basal portion, its breadth being about two-thirds of its length. It is provided, like the basipodite of the preceding and following appendages, with a long spine. Such spines are not serrated and are bent downwards and inwards towards the middle line of the body. The second segment is longer, but also stout, well provided with muscles, and has a spine on the dorsal side at its distal end. The first segment of the endopodite is slightly longer than the last and has two spines near its middle; it ends in three or more spines. The second segment of the endopodite is smaller, and has one large spine and two small ones at its extremity. The third segment is very long, being about four times the length of the preceding, and there are about ten long serrated spines scattered over its length; nearer to its distal extremity there is a group of four, whose bases are close together in a transverse line, and at its end, where it articulates with the last joint, is a group of about six. The last segment is short and ends in a long spine with two shorter ones at its base. The exopodite consists of a long proximal segment, with two spines near its middle and one at its distal extremity. The remainder of its length is divided up into short segments provided with long plumose setæ.

The *second pereopod* (fig. 19) is similar to the first.

The *third pereopod* (fig. 20) has the first segment short and stout, with a long spine as in the preceding limbs. The second segment is long and has a triangular leaf-like projection (the exopodite) at the beginning of the distal third. Three spines, one before and two after the exopodite, occur at this point, but the segment which appears in the next stage is, as yet, not to be seen. At the distal end there are two spines. The third and fifth segments are much longer than in the other legs.

Occurrence of Phyllosoma of 1.7 mm.

The first phyllosomas are readily procured by keeping crawfish with berry in a well-aerated aquarium. So far there has been no further success in the rearing of the young, no decidedly later stages having been observed in confinement.

This stage was also readily found in the sea. A series of eighty-five tow-nettings were taken at more or less regular intervals in Table Bay from January 1913 to May 1914, and numerous specimens were procured at certain times of the year. In all of these (over several thousands in number) no later stage was observed. The explanation of this may be that, in casting their cuticle at this stage, they go to the bottom, and this seems to be indicated also by the sudden disappearance of the phyllosomas from the tow-nettings after the 10th February, 1914, previous to which they were numerous. The procuring of a few cast cuticles on the 12th of the same month is also significant. These cast cuticles were quite identical in size and general character to the phyllosomas. Some of the tow-nettings had perfect phyllosomas together with cast cuticles, but no trace of the animals which had shed the cuticle.

Habits and Behaviour of Phyllosomas of 1.7 mm.

On hatching the naupliosoma rapidly ascends to the surface by means of its setose antennæ. The head region is uppermost and the antennules project upwards. The plane of the exopodite and endopodite and of the large parachute-like group of swimming setæ is mostly horizontal, and this is effected by the exopodite projecting toward the back of the body, one endopodite in a lateral direction. When the larvæ reach the surface they can progress in a horizontal direction, and they then seek out the most illuminated part. In a few hours (4-6) the phyllosoma stage is assumed. The legs are very much longer and project laterally, the exopodite upwards, the endopodite downwards and inwards, except in the case of the third, which projects out straight behind the body. The two pairs of exopodites of the first and second pereiopods are in active movement, and the long plumose setæ with which they are provided would appear to be very effective swimming organs. This, however, is not the case and the forward progress of the body is comparatively slow. From a purely mechanical point of view, they seem badly adapted for progression, as they project well over the centre of gravity of the animal, and their characteristic lashing movement (if too energetic) would result in the body turning a somersault—in fact, this occurrence was often observed. The preservation of the balance of this unstable body is, however, effected by the long third pair of walking-legs, which project backwards in the direction of the main axis of the body. They seem quite sufficient to counteract the toppling forward of the body referred to, which may therefore not have been so accidental as it seemed. It was observed also that the body could be made to rotate on its long axis by the movement of these legs, as they are directed away from each other posteriorly. Even with these steering organs, however, the activity of the exopodite is not at all proportionate to the progression of the body, and suggests a respiratory instead of, or in addition to, a locomotory function.

These phyllosomas at first sought the light rather quickly, and crowded in a dense mass to a corner of the tank, which at certain times was well lighted. Later, they were found throughout the water at all distances from the surface, and some of them were observed to seek the bottom and come up again. A number, at about the same stage of development, were put in a small glass vessel for better observation, and it was very easily seen, by altering the source of illumination, how readily they sought the light. For about six days they swam about in the tank and then disappeared. Towards the end of that period they seemed to avoid the light. To make certain of this, an active and healthy specimen was carefully watched in a small jar, and it was observed that, in about seven days, it began to avoid the light, and could be made to pass from any one part to another by illuminating the jar from various sides, but, whereas it at first sought the light, it now as obviously avoided it. This behaviour may have been due to abnormal conditions, but, taken in conjunction with the marked absence of later stages among the many thousands caught by the tow-net, would seem to confirm the suggestion that the phyllosomas go to the bottom after this stage. They may do so at each ecdysis.

PHYLLOSOMA OF 3·8 MM. [Fig. 21] Pl. 15.

The phyllosoma nearest the first in point of size is a single specimen, procured 50 miles south-east of Table Bay, by a tow-net on the beam of a trawl, working at a depth of 230 fathoms. It is somewhat imperfect, antennules and the distal end of the third maxillipede being broken off; the other features resemble those of the phyllosoma of 1·7 mm.

The endopodite of the *antennæ* is relatively large and has a distinct division halfway between the origin of the exopodite and the base of the flagellum. The exopodite is relatively smaller, being now only about half the length of the endopodite. The parts immediately surrounding the mouth (upper lip, *mandible*, lower lip, and *maxillæ*) are, so far as could be made out, similar to those of the first phyllosoma, but in relation to the cephalic shield, which has now grown very large, occupy a relatively small area of the under surface, the distance between the outer edges of the maxillæ being contained about 5 times in the breadth of the shield, in place of about 3 times, as in the first phyllosoma.

The *second maxillæ* are not different from those of the previous stage. They are slightly larger, being 0·16 as compared with 0·11 mm. in the first stage.

The *first maxillipede* seems to be entirely absent.

The *second maxillipede* resembles that of the previous stage in relative length of segments and in arrangement of setæ.

The *third maxillipede* has the first four segments in the same proportion as before, and there is as yet no trace of an exopodite.

The *first pereopod* is 5·23 mm. in length—that is, the length of the body (3·8) is contained in it 1·37 times, whereas the length of the body in the preceding stage is contained in the length of its first pereopod 1·7 times. The length of this appendage is therefore relatively less than in the preceding stages. This relative shortening has taken place least of all in the first and last segments, next in the third and fourth, then in the second, the greatest relative shortening being in the fifth segment.

The *second pereopod* is very similar to the first, but is somewhat longer by about half a millimetre. The increase is in the fifth segment, which is ·45 mm. longer than in the last appendage.

The *third pereopod* differs little from the two preceding. There is now a setose exopodite, considerably shorter, however, than those of the preceding pereopods.

The *fourth pereopod* consists of a short unsegmented limb 1·28 mm. in length; about ·4 mm. from its base there is a short exopodite ·22 mm. in length.

A great development of the digestive gland has taken place. The posterior lobes have not changed much, and are still quite separate from the main mass. The anterior lobes can also be readily made out, but the lateral lobes are much enlarged and have lost their trilobed condition.

PHYLLOSOMA OF 24 MM.

The cephalic shield has increased in relative size, being about 16 mm. broad and the same in length, or $1\frac{1}{2}$ times in the total length of the body. It extends backwards over the thorax to about a line joining the anterior points of the insertion of the first pair of walking-legs.

There is no trace of spines on the dorsal side of the shield. Anteriorly it is produced as a prominence, on which the base of the eye-stalk is inserted.

The *antennules* are three-jointed and have two terminal flagella, the outer extending 1 mm. beyond the peduncle of the antennæ.

The *antennæ* are about twice the diameter of the antennules. There are three well-marked segments, the first of which is shorter than the second, which is equal to the third; the last is terminated by a very strong spine on the inner side. Just beyond it is a joint in the flagellum, the breaking joint in the adult, and the segments of the flagellum begin to show faintly at some distance from it. The first section of the appendage, fused to the body and containing the antennal gland, shows no trace of demarcation from the head region. There is no trace of an exopodite. The upper lip, *mandibles*, and *first maxillæ* form a mass round the mouth, now smaller in proportion to the head region, being about 9 times in the breadth of the shield.

The *second maxilla* (fig. 22, p. 111) has increased greatly, chiefly in its distal segment, which has altered also much in shape. It has become expanded and produced posteriorly, so as to assume a foot-like shape. The first segment is also enlarged and slightly produced anteriorly.

The *first maxillipede* (fig. 23, p. 111) now appears, or rather reappears, in the form of a small stump, with two slight projections. It has, however, altered its position, being removed from the base of the second maxillipede and nearer that of the second maxilla, slightly overlapping it on the inner side. The rudiment of the exopodite is well marked under the cuticle.

The *second maxillipede* consists of five distinct segments as before, but about the first third of its length is a slight bulging on the posterior side, with a smaller one a little further on the anterior; these are apparently the first traces of the joint and exopodite which appear at this point in later stages.

The *third maxillipede* is very long and consists of seven distinct segments; there is no trace of an exopodite, except a slight bulging as before.

The abdominal region consists of four segments provided with pleopods with a simple biramose termination, the last with uropods and the terminal telson.

PHYLLOSOMA OF 26 MM.

Does not differ much from that of 24 mm.

PHYLLOSOMA OF 33 MM.

This stage is well characterised by the appearance of the gills, the rostral elevation, and the demarcation of the first segment of the antenna from the body. A further description of these will be given in considering the next size, of which more perfect specimens are available and which does not seem to differ essentially from this stage.

PHYLLOSOMA OF 35 MM. [Fig. 24] Pl. 16.

The total length is 35 mm. The length of the shield is 21 mm., breadth 22 mm., and it reaches to a line joining the centre of the bases of the second pereiopods. The greatest breadth of the thorax is 10·8 mm.

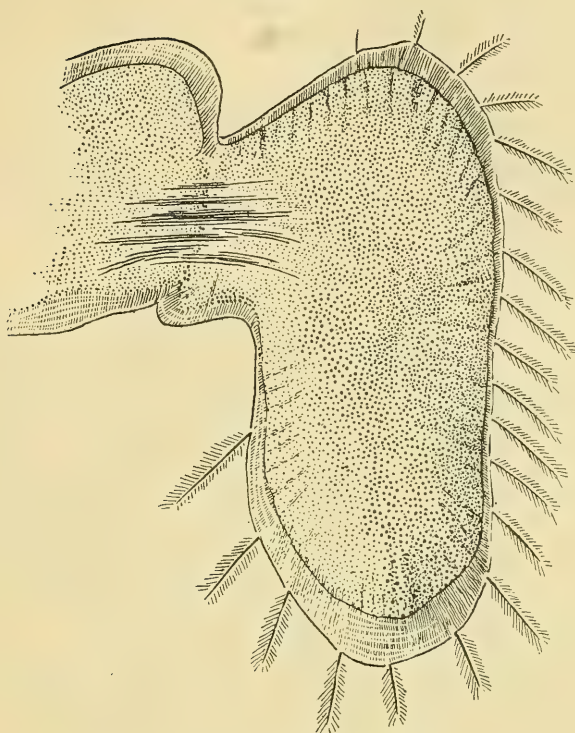
A feature not apparently observed in any phyllosoma hitherto described is the beginning of the rostral elevation, not a simple prominence as in the adult, but having a central projection with one in each side (fig. 25).

The liver is well developed and consists of numerous diverticula.

The eyes are on long stalks with a constriction near their distal end.

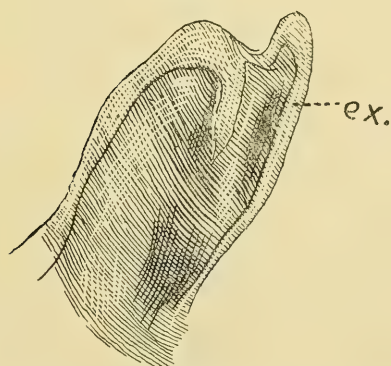
The *antennules* are well developed; the flagella are thick-segmented and

Fig. 22.



Second maxilla of *Phyllosoma* of 24 mm. $\times 97$.

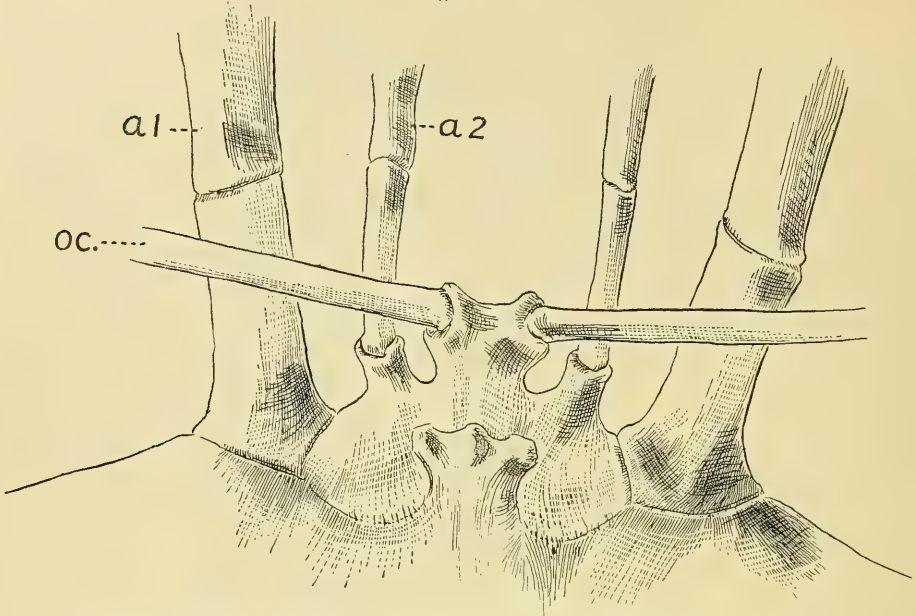
Fig. 23.



First maxillipede of *Phyllosoma* of 24 mm.

extend beyond the fourth segment of the antenna by about a third the length of the inner.

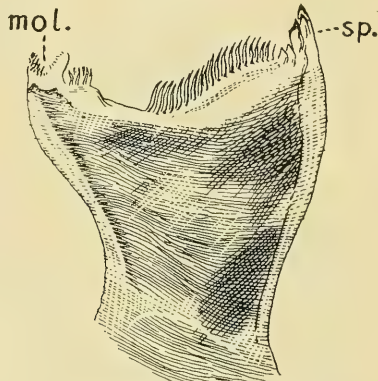
Fig. 25.



Anterior dorsal surface of *Phyllosoma* of 35 mm., showing rostral elevation.

The *antenna* consists of a basal segment, in which is lodged the antennal gland, and which can be seen to be marked off from the body.

Fig. 26.

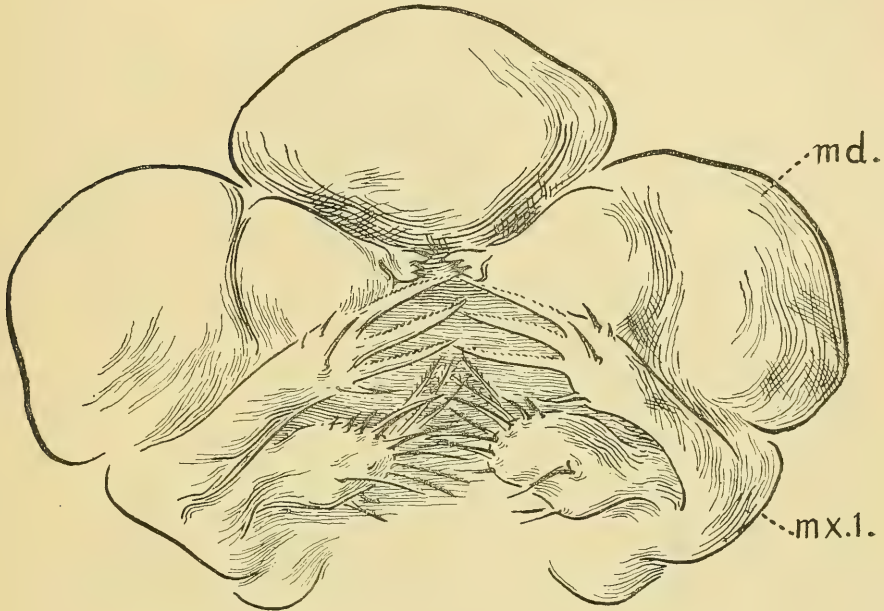


Mandible of *Phyllosoma* of 35 mm.

The *mandibles* (figs. 26, & 27, *md.*) are well developed, but of the same type as has been seen throughout. Each consists of a short undivided and

unbranched limb, the distal end of which is chisel- or gouge-shaped and lies almost at right angles to the body, so that the outer edge alone is seen when the animal is viewed from below (fig. 27, *md.*). At this outer edge the stout tridentate spine, already noted in an earlier stage, may be seen; it is followed by two short, rather blunt and thick spines, after which a series of longer, thinner, and sharper spines extending to beyond the middle of the mandible-edge, which may be described as the cutting part. Here they abruptly cease, so that it appeared at first as if they had been broken off, but this was observed

Fig. 27.

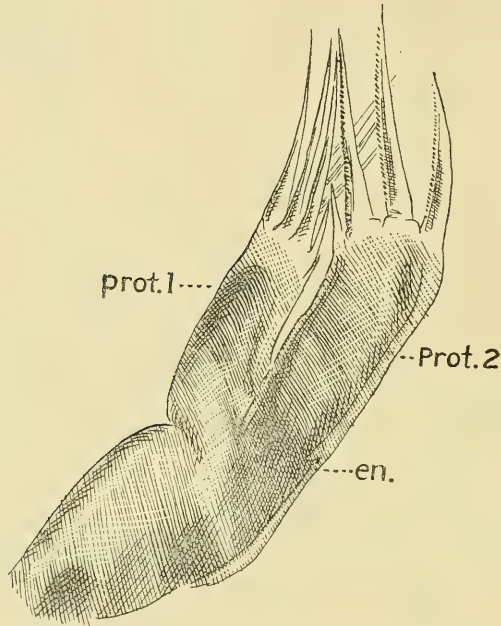
Mouth-parts of *Phyllosoma* of 35 mm.

also in other specimens and may be natural. The spines towards the middle are somewhat hook-shaped. After the interval devoid of spines there is another but smaller group of spines, close to the base of what may be termed the molar part of the mandible (fig. 26, *mol.*). This last is a characteristic cup or groove-shaped structure with projecting sides, forming a well-marked concavity, in which are situated a number of closely-set short spines, the whole forming a distinct projection which is reflected in the sub-cuticular tissue. This projection is of importance, as, later on, it apparently forms the flat molar surface of the adult mandible or part of it.

The *first maxilla* (figs. 28, & 27, *mx.1.*) is of interest chiefly in the appearance for the first time of a trace of the endopodite, not previously recorded in any phyllosoma. It is in the form of a small projection at the base of what is

commonly regarded as the second segment of the protopodite. The spines at the ends of these segments of the protopodite are very well developed ; on the first there are about half a dozen, long and rather slender, with

Fig. 28.

First maxilla of *Phyllosoma* of 35 mm.

lateral projection. A few short spines are inserted near the base. The second is provided with three well-developed spines, with lateral projections and one or two small spines occur at their bases.

The *second maxilla* (fig. 29) now shows four rudiments situated at its base, representing what are to become the endopodite and the three endites of the protopodite of the adult.

The *first maxillipede* (fig. 30) is furnished with a prominent exopodite and an epipodite. The differentiation of the endopodite and protopodite appears under the cuticle, but there is no division of the latter in two sections.

The *second maxillipede* consists of five segments : the first is not provided with a spine, but has the rudiments of an epipodite ; the second has, about its middle, a similar vesicular structure which corresponds to the exopodite of the other appendages. The distal end of the penultimate segment is provided with two strong bent spines, between which the short terminal joint with its strong spine can be bent.

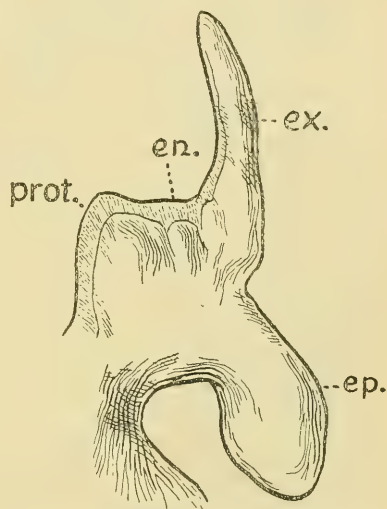
The *third maxillipede* is very long, and consists of five distinct segments: the first has a gill and spine; the second has the rudiment of an exopodite in the middle of its length, but no division; the third is short, the fourth is long and provided with numerous hair-like setæ. The third maxillipede of the puerulus and the adult has seven segments, of which the fourth is the longest, and the proportions are very different from those of this, the oldest

Fig. 29.



Second maxilla of Phyllosoma of 35 mm.

Fig. 30.

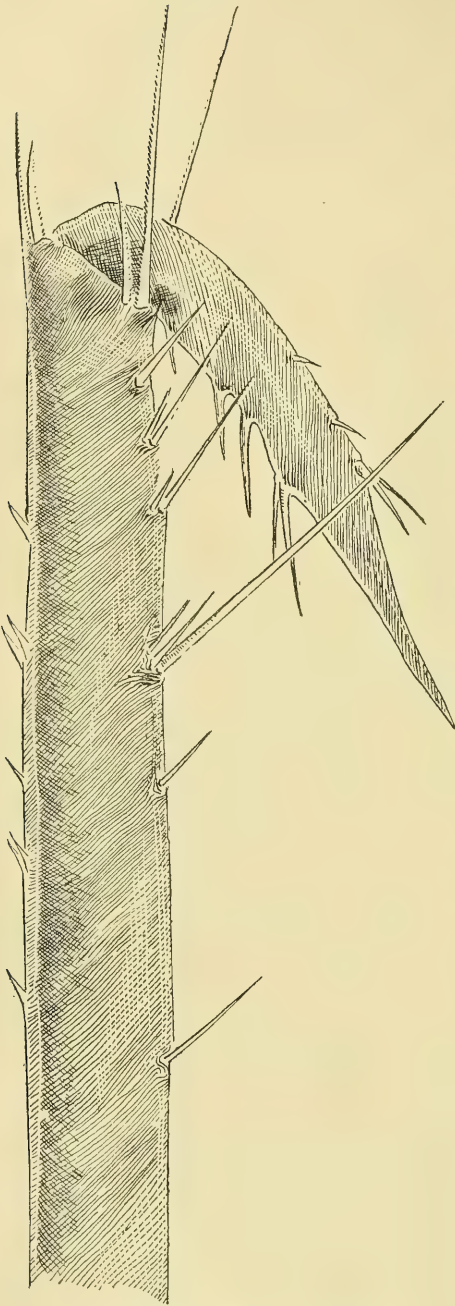


First maxillipede of Phyllosoma of 35 mm.

phyllosoma procured. Transition stages would probably show a great shortening of the second segment, a division near the proximal end of the third segment, and a very great shortening of the penultimate segment, making seven segments in all.

The *pereiopods* have well-developed gills (fig. 43, p. 120)—one podobranch with epipodite, one arthrobranch, and two pleurobranches. The position of

Fig. 31.



Distal end of second walking-leg of
Phyllosoma of 35 mm. $\times 25$.

the pleurobranch and arthrobranch will be described in more detail in connection with those of the puerulus, in relation to which they are of importance. It is of interest to note that this and the succeeding legs are terminated by a claw of a sub-chelate type, the last joint being bent over against the preceding (fig. 31).

There are well-developed exopodites on all of the pereopods except the fifth, where there is a very small rudiment; this rudiment, like the rudiment in the third maxillipede, resembles the vesicular structure which represents the first appearance of a gill, and suggests that the exopodite may represent a modified gill. The third segment of the fifth pereopod is relatively long.

The pleopods are present and well developed; their exopodites and endopodites are about equal in size, and in the latter is an appendix interna devoid, however, of setae and hooks.

The two chief spines on the upper surface of the telson are present, and the margins of telson and uropods are markedly denticulate.

The Rev. T. R. R. Stebbing (6) to whom, some years ago, I submitted a specimen very similar in general appearance and size, compared it with *Phyllosoma longipes*, Milne Edwards (5), and a phyllosoma described by Claus (3), and pointed out certain differences between them. That it is a stage in the life-history of *Jasus lalandii* can only be fully determined by a more complete series of specimens connecting it with the "puerulus"

stage. One characteristic seems to indicate that it is not so, namely, its much greater total length (from anterior end of carapace to posterior end of telson) than that of the puerulus or even later stages of *Jasus lalandii*, and this objection seems to be further strengthened by the recent observations of Bouvier (1) on the larval stages of *Palinurus vulgaris*. He has found what he regards as a complete series of stages between the early phyllosomas and the puerulus stage, there being a gradual increase in size in the total length, that of the oldest phyllosoma being equal to that of the puerulus. The objection, however, disappears when we remember that the total length of the phyllosoma includes the head region between the anterior end and the first maxillipedes. This region, which is nearly half the total length in a phyllosoma of 35 mm., must become enormously reduced before the adult stage, to whatever genus or species it may belong, is reached. The thoracic region also becomes relatively shorter as we advance from the first phyllosoma stage, and the only test of age in terms of length would appear to be in the abdominal region.

PUERULUS OF 22-26 MM. (Pl. 12 ; [Fig. 32] Pl. 17.)

This stage is transparent, but has still the characteristic red spots of the phyllosoma. These are very marked in the living state, but soon disappear on the death of the animal, if not kept in darkness. They occur chiefly on the under side of the body, as shown in the figure (Pl. 12), which was drawn by Mr. Birbel soon after the animal was captured.

The carapace on its upper surface is almost flat, being slightly convex in the cardiac region. The sides are bent downwards so as to be almost at right angles to the upper surface, but there is no very distinct ridge between sides and upper surface. Posteriorly the sides are not so well developed, and leave the gills partly exposed. There are slight but distinct traces of a cardiac and a pair of branchial grooves.

A few spines only are present. The most outstanding are the frontal or post-rostral. They project over the bases of the eye-stalk, pointing forwards and slightly inwards. Immediately behind them is a smaller pair, projecting forwards over the bases of the first. A little to the outside of this second pair, and behind the middle of each eye-stalk, is a somewhat larger (gastric) spine, behind which, and a little towards the side, is a strong (branchial) spine, from which the lateral ridge commences. Below the eye in the hepatic region is a strong spine. There is a single low median spine over the gastric region, and, posterior to it, towards the cardiac region, a pair of small spines, between which and the ridge spine is another small spine over the branchial region. Thus there are two pairs of frontal spines, three gastric, two cardiac, two pairs of branchial, one hepatic, corresponding to

the largest spines of the adult. No other spines were seen on the carapace. There are no sternal spines.

The rostrum is a very small simple projection, and does not appear to meet the ocular segment.

The *antennules* (Pl. 13. fig. 33, *a. 1*) are relatively short, the peduncle reaching to about the first third of the fourth segment of the antennæ. The flagella are, however, relatively stouter and longer than in the adult.

The *antennæ* (fig. 33, *a. 2*) are much longer than in the largest phyllosoma. The peduncle has the chief large spines of the adult, but the smaller scale-like spines are not yet developed.

The *mandibles* (Pl. 13. fig. 34), of all the other parts, show the greatest and most abrupt change from the phyllosoma conditions, but have not as yet assumed the adult characteristics. They thus present an instructive intermediate stage. The change is doubtless associated with the assumption of a ground habit, the mouth-parts being used for crushing up the harder shells, etc., on which the animal now feeds. The setæ, so prominent in the phyllosoma, are replaced by a thick cuticle. The incisor part can still be distinguished from the molar; it consists of a broad cuticle with two slight projections, which in some are hardly distinguishable, but are clearly represented in the subcuticular tissue, and, in later stages, become the two prominent teeth of the cutting-edge of the adult mandible. The molar part is in the form of a blunt well-marked projection, which has now come to lie somewhat behind the cutting-edge. In other words, the free edge of the mandible of the phyllosomas, consisting of cutting and mandibular parts, instead of forming a slightly curved edge, is now bent so as to form almost a circle. This can be clearly seen when the mandible is viewed from its distal extremity. It would appear therefore that the molar part of the mandible of the phyllosoma in the course of its development turns backward behind the cutting-edge, and assumes the flat hard character of the molar part of the adult mandible. The endopodite of the mandible, no trace of which was found in the phyllosomas, now appears, but consists only of one distinct segment. The beginning of the mandibular spine is also seen.

The *first maxilla* (Pl. 13. fig. 35) has now assumed the foliaceous form of the adult. The protopodite is deeply cleft into two segments, and near the base of the second a small endopodite appears, about half of its base arising from the inner side, so that it is not clearly seen when viewed from below. All the spines have disappeared, though a few were seen on the anterior border of the coxopodite and basipodite on one specimen. The appendage is now removed from the base of the lower lip by a distance equal to the length of the coxopodite.

The *second maxilla* (Pl. 13. fig. 36) has the three endites of the protopodite relatively larger than in the adult condition and provided with a few setæ. The endopodite is relatively much smaller and is triangular instead of convex,

as in the adult; it has only a few setæ. The exopodite (scaphognathite) is well developed and provided with feathered setæ.

The *first maxillipede* (Pl. 13. fig. 37) does not differ essentially from that of the adult, but the endopodite is smaller and lies more to the inner side of the exopodite.

The *second maxillipede* (Pl. 13. fig. 38) differs from the adult condition in that the flagellum of the exopodite is not segmented, and the last segment of the endopodite is provided with a short spine at its tip.

The *third maxillipede* (Pl. 13. fig. 39) is characterised by a very short exopodite, consisting of one undivided segment, about half the length of the first segment of the endopodite, which lies alongside of it. The last three segments of the endopodite are provided with long serrated spines on their inner surface.

The *first pereopod* (Pl. 13. fig. 40) shows the long basipodite of the phyllosoma reduced to a mere ring of chitinous tissue, narrower on the upper side than on the lower. At its narrowest point there is a projection of irregular outline, and of a clear refractile substance; this appears to be the remains of the exopodite.

Some of the spines of the limbs are of interest. In the phyllosoma there occurs, at the distal end of the fourth segment of the leg, two spines evidently of a defensive function. Here, as in the adult, their position is taken by the projection, on which is the socket of the "ball-and-socket" joint, between the segments, and their place is taken functionally by a single median spine which now appears for the first time. It would appear that this pair of defensive spines of the phyllosoma may be transformed to form the joint of the adult, and this may be true also of all the other joints of a similar nature.

Fig. 42.



Epimera of oldest Phyllosoma, Puerulus, and adult.

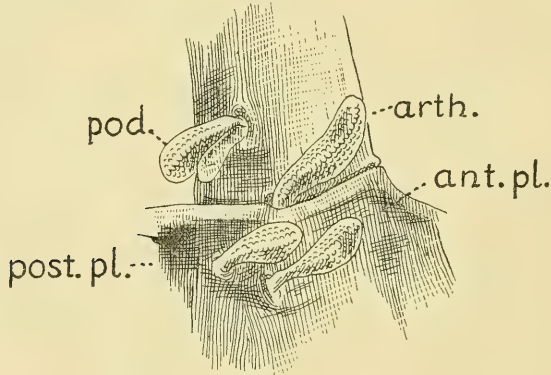
The *pleopods* (Pl. 13. fig. 41) are all more or less similar, and have large flat exopodites and endopodites, provided with feathered setæ. There is a coupling projection on the inner side of each endopodite, provided with a feathered spine and hooks at its base.

The telson has a second pair of spines, rather faintly marked, situated behind the pair already seen in the last phyllosoma.

The shape of the epimeron is intermediate between that of the last phyllosoma and the adult (fig. 42).

The gills of the puerulus are of interest, as they seem to point to the solution of a difficulty connected with the difference in position of the gills in the phyllosoma and the adult. In the adults of the Scyllaridæ and all decapods generally there are (it is believed) one pleurobranch, two arthrobranchs, and one podobranch, while in the larval forms (phyllosomas) there are clearly two pleurobranchs, one arthrobranch, and one podobranch. This difference between the young and adult forms is well known, and it is desirable to ascertain whether the adult condition is a primary or secondary one. There can be no doubt that the arthrobranch of the phyllosoma is placed on the joint (fig. 43) and that it is well separated from the two pleurobranchs. These latter occur on the dorsal side of the flattened thorax, and the name is therefore not strictly accurate. The real side or pleuron of

Fig. 43.



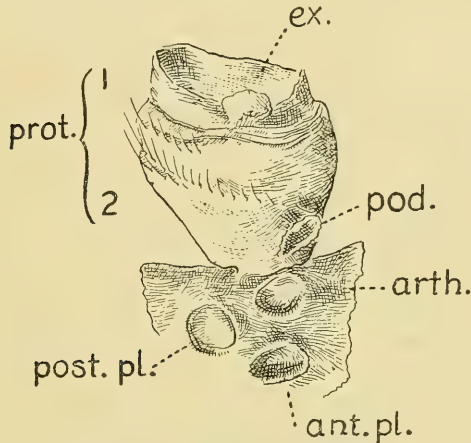
Gills of *Phyllosoma* of 35 mm.

the thorax is still in the form of a thick cuticular rim, which, although rather thinner at the insertion of the appendage, still forms a marked ridge separating the arthrobranch clearly from the pleurobranchs, so that frequently, when viewed from above, only part of the arthrobranch can be seen, protruding from under the edge of the thorax, which overhangs the base of the limb. The two pleurobranchs (on the 2nd to the 4th walking-legs) are at some distance from this edge and are thus clearly separated from the joint and its gill-rudiment. They are also well separated from each other, and it is particularly to be noted that the posterior is distinctly nearer the side of the body than the anterior. This has been noted in all the phyllosomas examined and may occur in other phyllosomas, though the point has not been particularly noted.

In the puerulus stage the thoracic region has become much deeper,

narrower, and shorter, and this has brought about a considerable change in the relative positions of the gills. The rim of the thorax has disappeared as such, and no longer forms a projection separating the pleurobranchs from the arthrobranch. The position of the two pleurobranchs with reference to each other has changed. The first or anterior, formerly only slightly further from the arthrobranch than the second, is high up on the now vertical wall of the thorax, while the second has remained low down. This rearrangement of the pleurobranchs is, of course, in co-ordination with the shortening and heightening of the side of the thorax (fig. 44).

Fig. 44.



Positions of gills of Puerulus.

With the disappearance of the rim of the thorax there is no clear separation between the single arthrobranch and the nearest pleurobranch (the posterior), so that it is now scarcely possible to draw any clear distinction between arthrobranchs and pleurobranchs, and the functional joint has now become enlarged to include the bases of these two gills. When calcification of the sides of the thorax sets in, in later stages, the anterior gill is completely separated from the other two. The adult condition may therefore be described as brought about by the posterior pleurobranch of the phyllosoma becoming an arthrobranch in the adult. It may, however, be noted here that it is not quite correct to state that there are two arthrobranchs in *Jasus*, as the posterior of these is marked off from the joint by a slight calcification clearly seen in cast shells.

In the next stage of *Jasus lalandii* the branchiæ have not altered much in their position and relation to the coxa and its proximal joint. The cuticle generally has become calcified, but the pleura only slightly. A slight deposit of carbonate of lime is seen below the base of the first or anterior pleuro-

branch, separating it still more effectively from the second. Ultimately the calcification extends completely round the first and over the pleura generally, and the anterior pleurobranch is still higher up the side.

The puerulus here described does not quite agree with that described by Bouvier (2) from the island of St. Paul, and suggested by him to be that of *Jasus lalandii*. Thus, there is no very distinct dorso-lateral ridge, and there are fewer spines on the dorsal region of the carapace; the exopodite of the third maxillipede does not nearly reach the articulation of the ischiopodite with the meropodite as in his specimens. The frontal spines are, however, slightly convergent, and it may represent an earlier stage than that described by Bouvier. Gruvel (4) also describes some young forms of this species from the island of St. Paul, but not in sufficient detail for a comparison with our specimens.

Review of Results.

The larvæ of the first and second stages of *Jasus lalandii* can readily be hatched out from the egg. Larvæ of the second stage were found in abundance in the inshore waters during the summer months, and a much smaller number of more advanced stages (up to 37 mm. in length) in deep waters. The puerulus stage can be found close inshore. These were all found on the west coast of S. Africa, and are regarded as stages of *Jasus lalandii*, the only known representative of the Scyllaridea in this region, where it occurs abundantly.

Three other kinds of phyllosoma and two kinds of puerulus occur on the south and east coasts, apparently belonging to other South-African Scyllaridea (*Palinurus*, *Panulirus*, and *Scyllarides*).

The appendages of the first or naupliosoma-stage are described and figured. The second or phyllosoma-stage (1.7 mm.) differs from it in the absence of the swimming setæ of the antennæ, the appearance of the flagellum of the endopodite, the presence of olfactory (?) filaments on the antennules, etc. A phyllosoma of 3.8 mm. shows relative increase in size of shield, decrease in length of walking-legs, diminution of the exopodite of the antenna, absence of first maxillipede, appearance of the fourth walking-legs, etc. A phyllosoma of 24 mm. shows still greater relative increase in size of shield, flagella appear on antennules, antennæ are three-jointed and their exopodites have disappeared, the distal part of the maxilla has broadened out and expanded posteriorly to form the scaphognathite, the first maxillipede reappears as a simple stump with two slight projections, and pleopods appear as simple biramous organs. A phyllosoma of 26 mm. shows no essential change, but in one of 33 mm. the gill-rudiments appear and a rostral elevation with three prominences, the middle one of which may represent the rostrum, the other two the ocular spines. The mandible consists of three strong spines, followed by a series of small spines, inserted on an elongate edge and

separated by an interval from a molar-like part. A trace of an endopodite appears on the second maxilla, and the endopodite and endites of the proto-podite appear on the second maxilla. The first maxillipede has the beginnings of an exopodite and an epipodite.

The puerulus shows the typical characteristics of this stage—transparent soft cuticle, few spines on carapace, bases of the third maxillipedes well separated, antennular peduncle short, coupling-hooks on the appendix interna. The puerulus in its natural state, though transparent, is not colourless and has the red spots characteristic of the phyllosoma. The condition of the mandible indicates the method of transition between the phyllosoma and adult state, the molar part becoming turned round, somewhat behind the incisor part.

Observation of the habits of the living animal shows that the naupliosoma stage moves towards the light and undergoes ecdysis without descending from the surface of the sea. The second stage at first also seeks the light, but later on avoids it, and seems to descend from the upper layers of the water on ecdysis.

The exopodite on its first appearance has the same general appearance and position with regard to the limbs as the rudiments of the gills. It is therefore suggested that the exopodite has arisen from a former gill. Observation of the living naupliosoma seems to indicate that the exopodite has still an important respiratory function.

A feature common to all the stages of the phyllosoma examined is that the last pair of well-developed walking-legs are relatively long and, probably in all stages, act as steering-organs, as was observed to be the case in some living specimens. The lengthening of this limb is chiefly in the first segment of the endopodite, and this may prove to be a diagnostic characteristic of the species.

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EXPLANATION OF PLATES AND TEXT-FIGURES.

PLATE 12.

Puerulus of *Jasus lalandi*, showing natural colours, ventral aspect.

PLATE 13.

Fig. 1. Antennule of the Naupliosoma.

- | | | |
|--|---|---|
| 2. Antenna | " | " |
| 3. Mandible | " | " |
| 4. First maxilla | " | " |
| 5. Second | " | " |
| 6. First maxillipede of the Naupliosoma. | | |
| 7. Second | " | " |
| 8. Third | " | " |
| 9. First pereopod | " | " |
| 10. Second | " | " |
| 11. Third | " | " |

PLATE 14.

Fig. 12. Phyllosoma of 1·7 mm.

PLATE 15.

Fig. 13. Antennule of Phyllosoma of 1·7 mm.

- | | | |
|---|---|---|
| 14. Antenna | " | " |
| 15. Mandibles, first maxillæ, second maxillæ, and first maxillipedes of Phyllosoma of 1·7 mm. | | |
| 16. Second maxillipede of Phyllosoma of 1·7 mm. | | |
| 17. Third | " | " |
| 18. First pereopod | " | " |
| 19. Second | " | " |
| 20. Third | " | " |

PLATE 16.

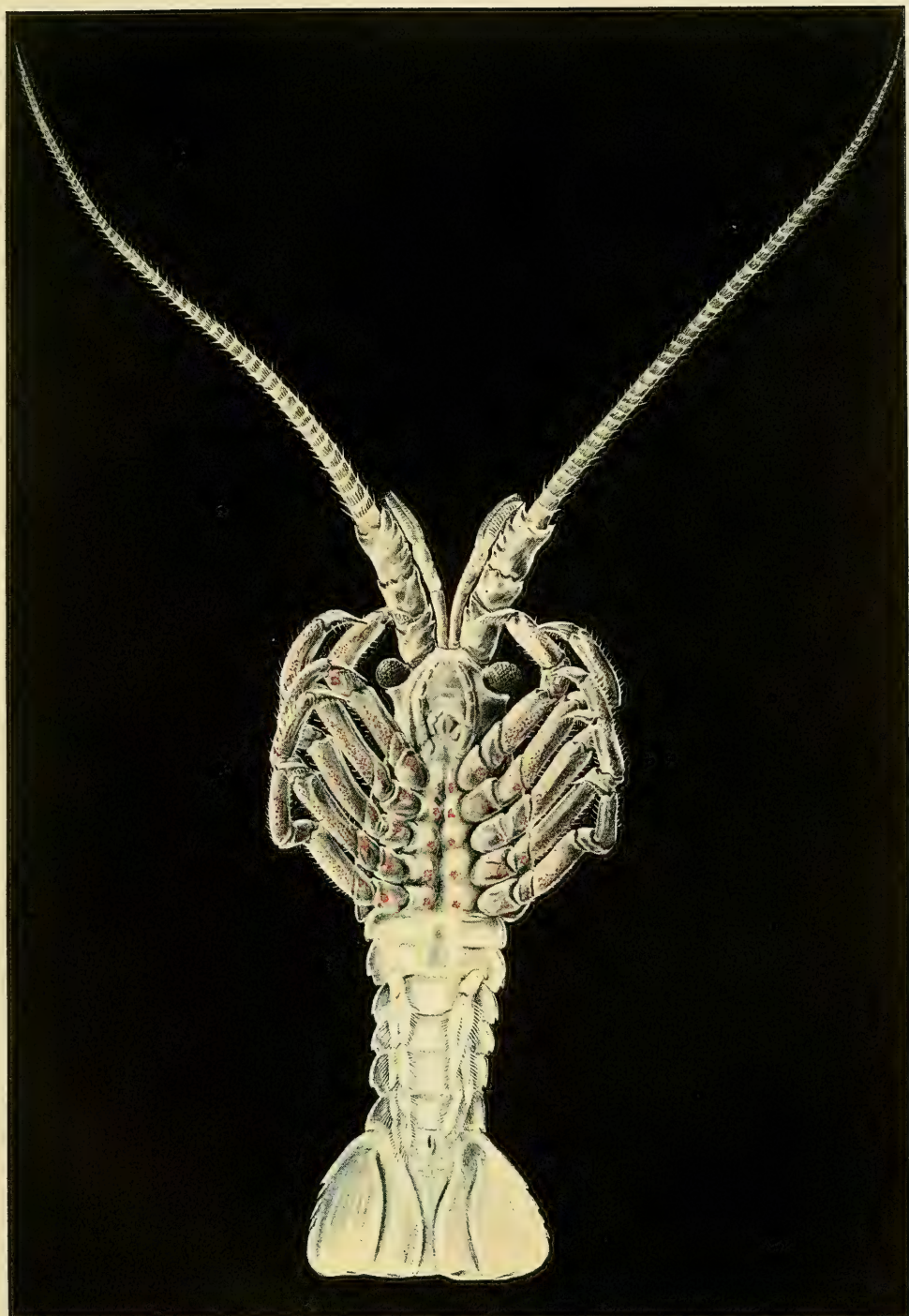
Fig. 21. Phyllosoma of 3·8 mm.

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23. First maxillipede	" " 111.

PLATE 16.

Fig. 24. Phyllosoma of 35 mm.

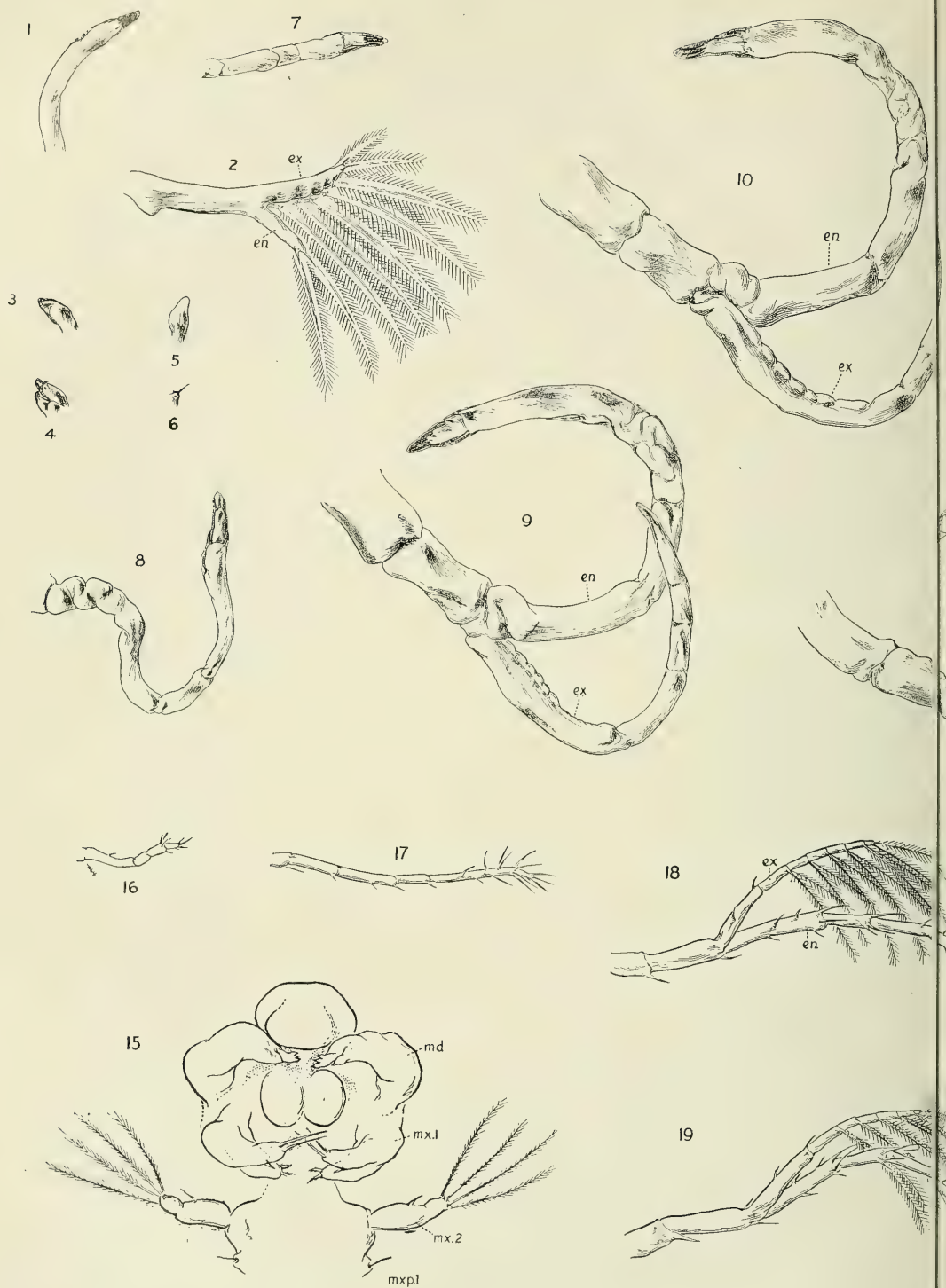
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28. First maxilla	" 114.
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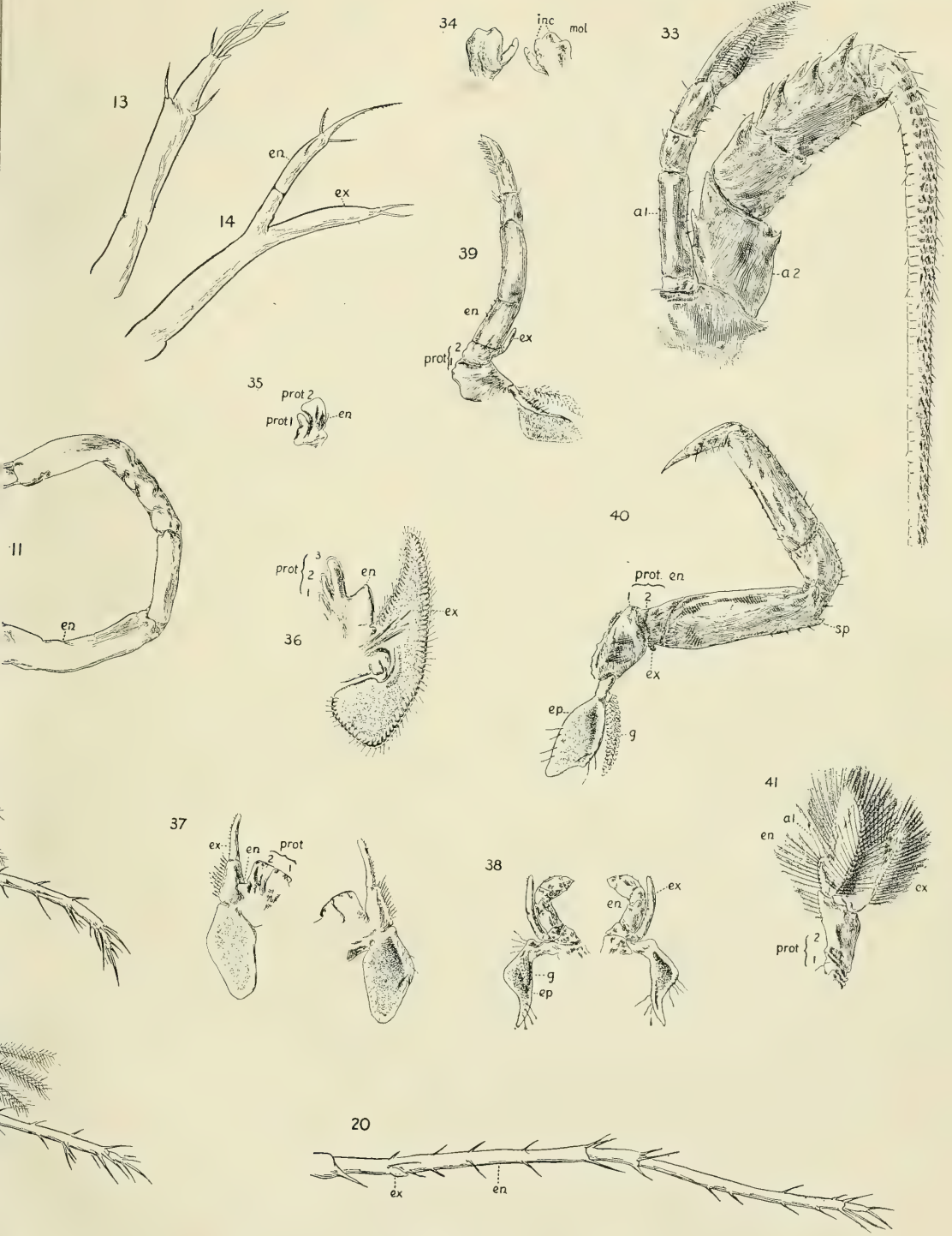


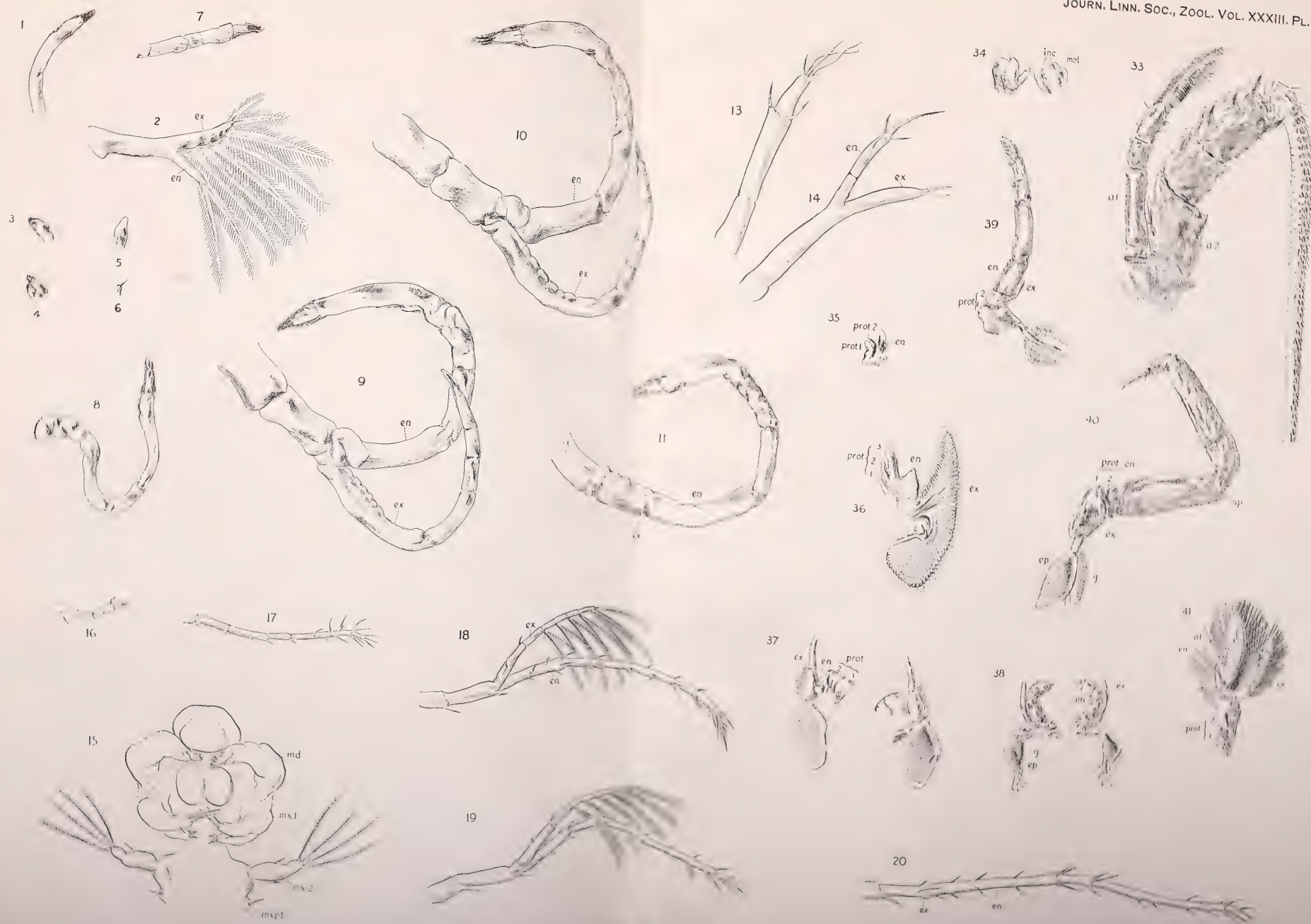
J. Birbel, del.

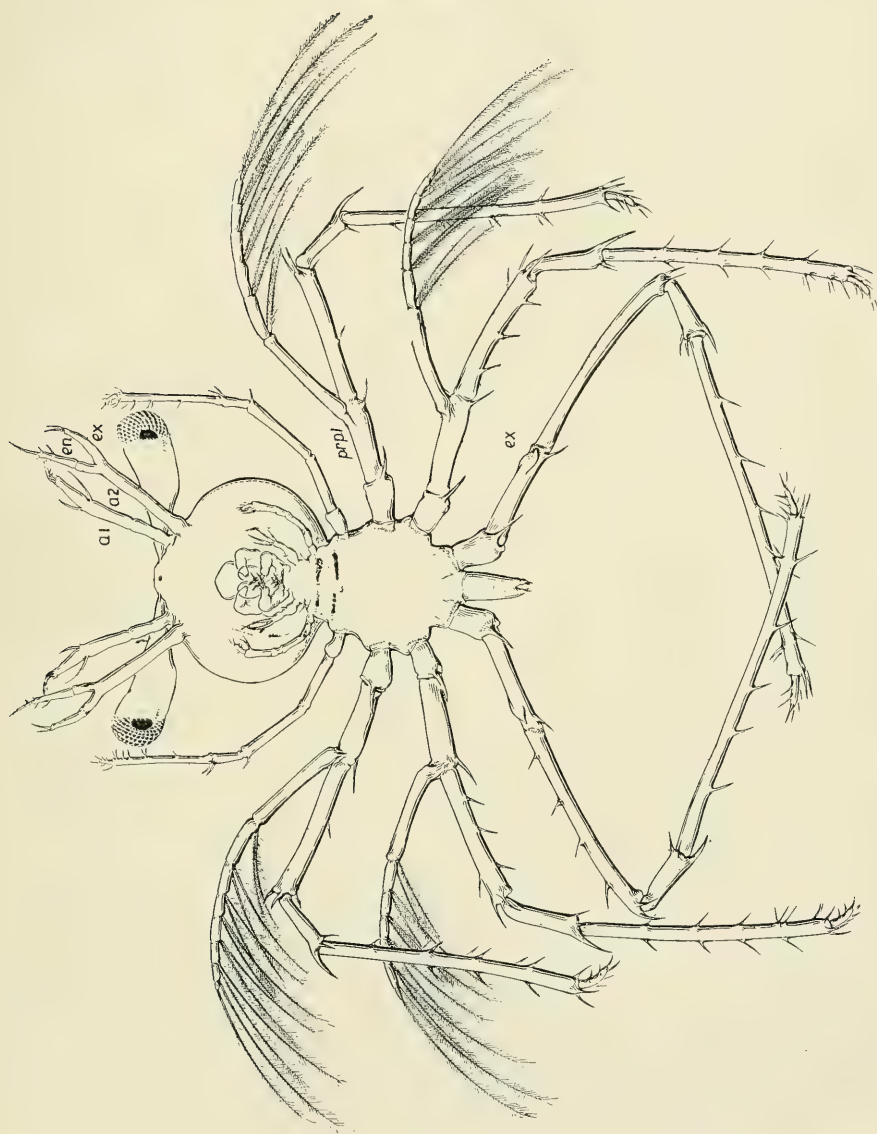
Grout, sc. & imp.

JASUS LALANDII.

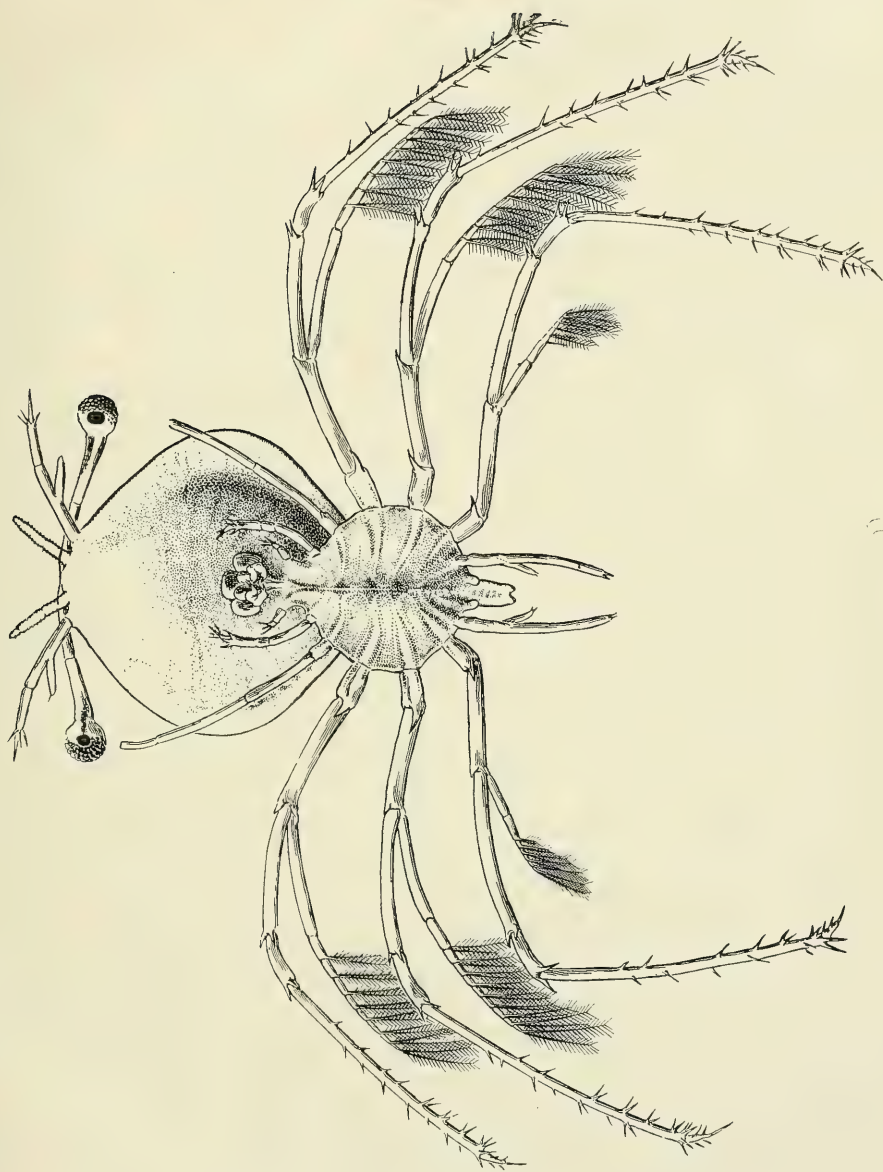




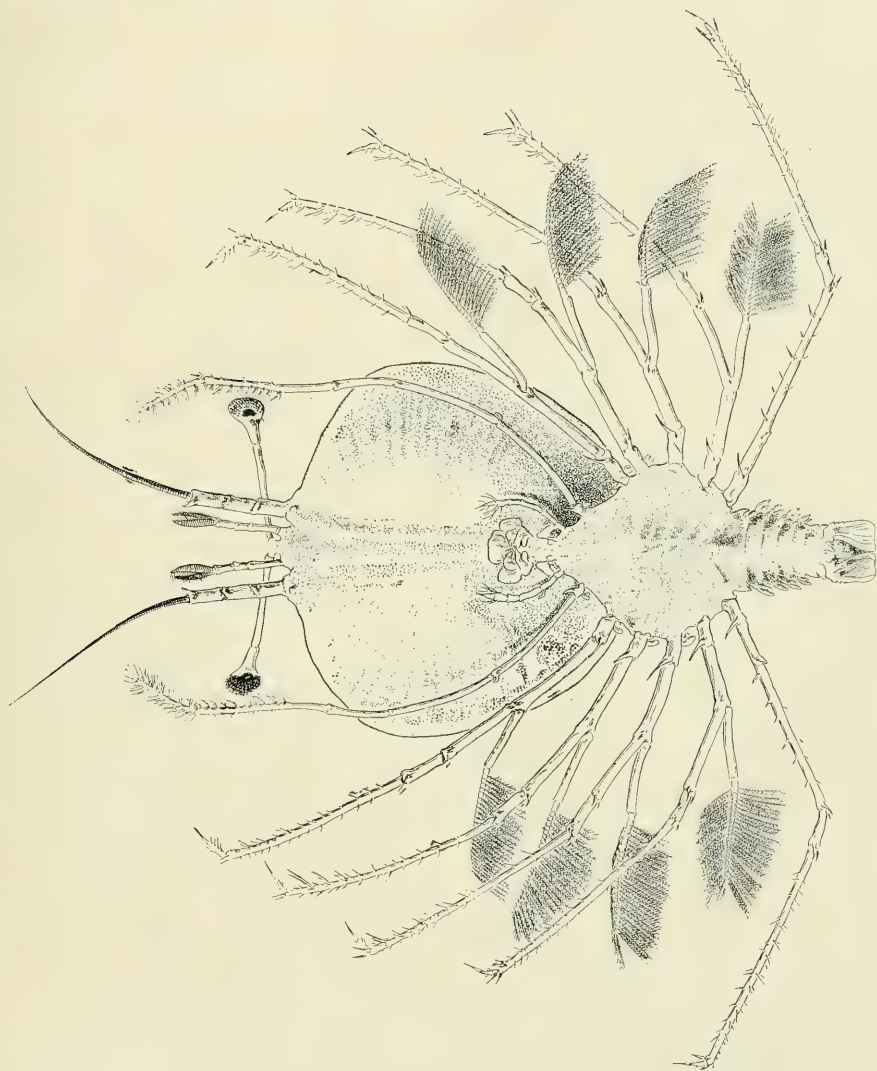




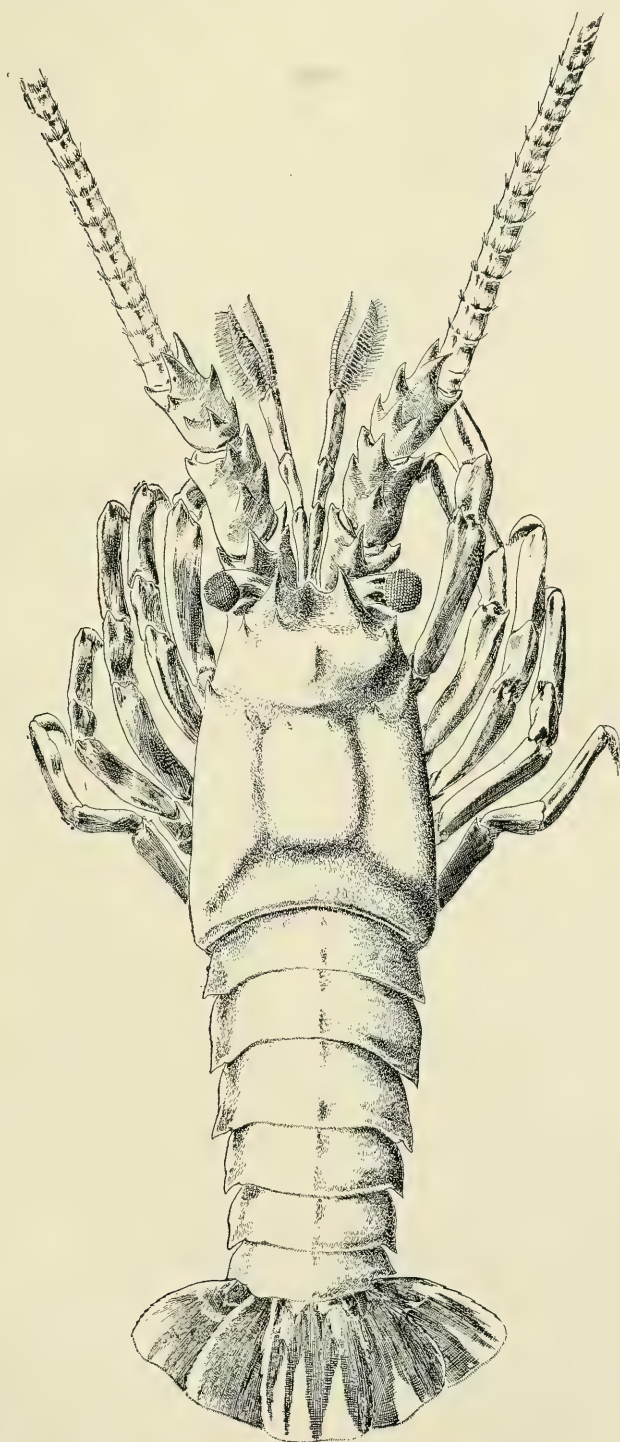
JASUS LALANDII (Milne Edw.) Ortm.



JASUS LALANDII (Milne Edw.) Ortm.



JASUS LALANDII (Milne Edw.) Ortm.



JASUS LALANDII (Milne Edw.) Ortm.

PLATE 17.

Fig. 32. Puerulus of 22 mm., dorsal view.

PLATE 13.

Fig. 33. Antennule (*a. 1*) and Antenna (*a. 2*) of Puerulus of 22 mm.

34. Mandible of Puerulus of 22 mm.

35. First maxilla " "

36. Second " " "

37. First maxillipede " "

38. Second " " "

39. Third " " "

40. First pereopod " "

41. Pleopod " "

Fig. 42. Epimera of oldest Phyllosoma, Puerulus, and adult. Page 119.

43. Gills of Phyllosoma of 35 mm. " 120.

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List of Abbreviations.

<i>a. 1.</i> Antennule.	<i>mol.</i> Molar part of mandible.
<i>a. 2.</i> Antenna.	<i>mx. 1 & mx. 2.</i> First and second maxillæ.
<i>a. i.</i> Appendix interna.	<i>mxp. 1 to mxp. 3.</i> First to third maxilli-
<i>arth.</i> Arthrobranch.	pedes.
<i>en.</i> Endopodite.	<i>pl.</i> Pleurobranch.
<i>ep.</i> Epipodite.	<i>pod.</i> Podobranch.
<i>ex.</i> Exopodite.	<i>prot.</i> Protopodite.
<i>g.</i> Gill.	<i>prp.</i> Pereiopod.
<i>inc.</i> Incisor part of mandible.	<i>sp.</i> Spine.
<i>md.</i> Mandible.	

A Study of the Rectal Breathing-Apparatus in the Larvæ of Anisopterid Dragonflies. By R. J. TILLYARD, M.A. (Cantab.), B.Sc. (Sydney), F.L.S., F.E.S.

(PLATES 18-22, and 21 Text-figures.)

[Read 4th May, 1916.]

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INTRODUCTION.

THE present paper is the outcome of a suggestion made to me some three years ago by my friend Dr. F. Ris, of Rheinau, Switzerland. Being unable to spare the time to carry out the researches which he had begun, and of which he later on published a short account (23), he very kindly suggested that I should take up the subject, which promised to yield many interesting facts new to science. Through his generosity in giving me full information as to his methods, and in sending me a set of prints of his very beautiful but unpublished microphotographs, I was able to apply his methods to the rich Australian material at my disposal. The immediate result of this was the discovery of a number of new and interesting forms of rectal breathing-apparatus. Later, I undertook the study of the finer details and histology of these organs by means of microtome-sections. This method again yielded a number of new facts not less in interest than the former, although the great

complexity of the gill-formation made the investigation in almost every case not only a difficult one, but very long and tedious.

In order to avoid prolonging the investigation unduly, I have found it necessary to postpone not only the physiological study of the respiration, as carried on in the rectum, but also to confine my attention almost entirely to mature or fairly mature nymphs. A complete phylogenetic study demands, of course, a thorough investigation also into the successive ontogenetic changes that take place at each ecdysis throughout the growth of each larva studied. This would, however, be a matter not of months merely, but of years. In the twelve months during which this work has been carried out, I was only able to study the ontogenetic gill-development in two genera (*Aeschna* and *Anax*)—fortunately, genera which throw much light on the phylogenetic problem. The object of the paper may therefore be briefly stated as an attempt at a complete morphological study of all obtainable forms of rectal breathing-apparatus in Australian Anisopterid dragonfly nymphs, with some phylogenetic deductions which appear to me to be fully warranted by the facts therein established.

Some of the facts made known for the first time in this paper do undoubtedly throw light upon the very difficult physiological questions involved. It seems to me, however, to be unsafe to draw physiological conclusions, as Sadones (25) has done, from purely morphological and histological studies. I therefore prefer to hold over this aspect of the question until a later date, when perhaps physiological experiments may have yielded more conclusive evidence than can be to-day offered in support of any theory of respiration in these insects. If at any point I have touched upon the physiological aspect of the problem, it is because that aspect happens to stand out very clearly in relation to the facts in hand, and not because they offer anything like a complete or satisfactory solution of the problem.

I should like to express my thanks to Professor W. A. Haswell, F.R.S., under whom this research has been carried out, for much kindly encouragement and sound advice; while to Dr. F. Ris I am indebted for the origination of the subject and also for valuable criticism during the progress of the research.

HISTORICAL SUMMARY.

In the appended Bibliography there will be found a complete list of all the authors known to me who have mentioned the rectal breathing-apparatus of Odonate larvæ. These peculiar rectal structures seem to have been noticed first by Swammerdam (28), though the actual recognition of them as a breathing-organ is probably due to Poupart (20). The respiratory function of the rectum was also known to Réaumur (22), de Geer (9), Cuvier (3), Duvernoy (6), Marcel de Serres (14), Lyonnet (13), Suckow (27), and

Ratzeburg (21). But it was Dufour (5) who made the first real advance in the knowledge of the true nature of these organs. He showed that tracheæ penetrated into the projecting folds of the rectum, which thus are actually of the nature of *tracheal gills*. To Dufour also we owe the first definite assertion that the complicated rectal breathing-apparatus studied by him in the larvæ of *Libellula* and *Æschna* did not occur in the Zygoptera. His discovery of three longitudinal folds in the rectum of *Calopteryx*, which he considered to be poorly developed breathing-organs, does not concern us directly here. But, as this function has been denied to them by recent authors, we may well point out that this aspect of the problem needs fuller investigation.

After Dufour, the subject was briefly touched upon by Milne-Edwards (17) and Leydig (12). The latter author was the first to discover the important fact that the finest tracheal capillaries ramifying in the gills do not end blindly in them, but form *complete loops*. Leydig, however, was not at all seized with the importance of this discovery, which he announced in two lines of text, without giving a figure. It is, therefore, rather to Oustalet (18) that the real honour belongs of investigating this point. His description and figures are far in advance of any previous work on the subject, and mark a very distinct step forward in the progress of our knowledge.

Following Oustalet, Chun (2) was the first to study the *histology* of the rectum. He gives a figure purporting to show a transverse section of one of the gill-lamellæ of *Libellula depressa*, Linn. But, as Sadones (25) has shown, this figure is incorrect in very many details; and, besides failing to recognize the existence of the tracheal loops, established by Oustalet, it certainly does not belong to the genus to which it is assigned by its author. In fact, it may be stated definitely that no histological structure belonging to any known Odonate gill-type can be found which at all corresponds with Chun's figure. It is, indeed, very difficult to explain how his figure originated, except as the product of an imagination rather more fertile than accurate.

After Chun, Poletaiëw (19) contributed a paper, which is of value in being the first evidence of a disagreement with the generic determination of one of the larvæ studied by Dufour and Oustalet. This larva, which we now know for certain to have belonged to the genus *Anax*, was called *Æschna* by these authors. Poletaiëw, in examining undoubted larvæ of the genus *Æschna*, failed to find the papillæ so carefully described by Oustalet. Hence, she questions the accuracy of the descriptions of that author and of Dufour. None of these authors seem to have attempted to breed out any of the larvæ which they were studying. The facts are, of course, well known to all Odonatologists at the present time, thanks to Ris (23), viz. that the gills of *Anax* bear papillæ, while those of *Æschna* do not.

Amans (1), Roster (24), Faussek (8), R. Martin (15), and Dewitz (4), have all contributed to the study of the structure of the rectum and its tracheal

connections, but without making any notable addition to our knowledge of these organs. Miall (16), East (7), and Latter (11) have contributed popular accounts of the same structures.

The greatest advance in our knowledge of the subject is undoubtedly due to Sadones (25), who, working under Professor Gilson (10), produced in 1896 a classical memoir on the whole digestive tract of the larva of *Libellula depressa*. The outstanding merit of this work is the careful and accurate study of the histology of the rectal epithelium, and the part played by it in the formation of the gill-lamellæ. Sadones's original contributions to the subject include (1) the discovery of the basal pads of the lamellæ; (2) the discovery of the small tubercles on the lamellæ, which prevent them from lying too closely upon one another; (3) the demonstration of the complete continuity of the rectal epithelium as a fine *syncytial matrix* beneath the whole branchial cuticle; and (4) the fixing of the definite position of the tracheal capillary loops as running in this syncytium. To him, also, we owe a very clear criticism of Chun's description and figure. Sadones, however, seems to us to have forsaken firm ground when he turns to the physiological aspect of the subject. His theories concerning the absorption of oxygen and the elimination of carbon dioxide, whether they be ultimately proved correct or not, show a distinct lack of understanding of the closed tracheal system as it exists in Odonate nymphs, and are quite unsupported by any of that definite evidence which the importance of the subject demands.

After Sadones, the subject remained untouched for sixteen years (except for a short account by Scott (26), who added nothing new to our knowledge) until Ris (23) published, in a short but very valuable paper, the results of his comparative studies on the rectal gills of a number of European Anisopterid larvæ. Ris described the gill-structures in the following genera:—*Cordulegaster*, *Gomphus*, *Onychogomphus*, *Brachytron*, *Æschna*, *Anax*, *Cordulia*, *Orthetrum*, *Libellula*, and *Sympetrum*. In these ten genera he recognizes six distinct types of gill-formation. He also shows how these structures are found to be both more morphologically complex and physiologically perfect as we pass from genus to genus along the phylogenetic tree, as it has been already constructed for us on the venational characters of the imagines. Ris made a very beautiful series of microphotographs of the various types of gills; but these were unfortunately never published, owing to the difficulty of finding a process which would reproduce them satisfactorily.

Following on all these authors, it now remains for me to extend the methods and observations of Ris to our rich Australian fauna, and also to attempt the more difficult histological study of each new type, on the lines adopted by Sadones in his classical memoir on *Libellula depressa*. These two objects achieved, there remain some interesting phylogenetic considerations to be given, which will be found included in this paper.

TERMINOLOGY.

Various names have been applied by the authors cited above to the rectal breathing-apparatus and its parts. As there seems to be little unanimity between them, and as definite English equivalents seem still to be lacking for the names given by the French and German authors to whom the progress of our knowledge is almost wholly due, I offer here the following terminology, which will be used throughout this paper :—

The *Rectum* proper consists of all that portion of the hind-gut lying posterior to the dilated ampulla (*pre-rectal ampulla*) into the anterior end of which the small intestine enters. It consists of two distinct portions, a small posterior or *anal portion* containing six longitudinal raised epithelial pads (the so-called “rectal glands”), and a much larger anterior or *respiratory portion* containing the breathing-organs. To this latter portion, with which this paper has to deal, the term *Branchial Basket* or *Gill-basket* will be applied.

The folds of the rectal wall, which project into the cavity of the rectum and perform the respiratory function, will be spoken of generally as the *gills* or *gill-folds*. In a gill-fold, each of the two walls forming the eversion will be called a *gill-wall*. The two gill-walls forming any given fold are therefore continuous with one another at the free distal border or edge of the gill-fold. Each gill-wall is formed of a thin *epithelial matrix* with an outer secreted *cuticle* of excessive fineness.

The thickened epithelium which occurs at the bases of the gill-folds will be spoken of as the *basal pad* (“bourrelet épithélial” of Sadones).

The peculiar mass of tissue which lies at the base of each gill, carrying the efferent tracheæ, and covered either on one or both sides by the basal pad, will be called the *hypobranchial tissue* (“tissu adipeux” of Sadones).

When the gill-basket of an Anisopterous larva is opened, the gills are seen to lie in six longitudinal rows at equal intervals apart. Each of these rows will be termed a *holobranch*. Two main types of gill-basket are readily recognizable. In the simpler type, each holobranch consists of a single *longitudinal gill-fold*, supported at regular intervals, to right and left alternately, by smaller *cross-folds*. This type of structure will be called a *Simplex System*. In the second and more complicated type, there are no continuous longitudinal gill-folds; but each holobranch consists of a double row of smaller gills arranged more or less transversely to the long axis of the gill-basket. Each of these rows will be called a *hemibranch*. The number of gills in a hemibranch varies from twelve to thirty. This second type of gill-structure will be called a *Duplex System*.

The exact positions of the gill-rows or gill-folds in a transverse section of the rectum are of the greatest importance, if one would correctly understand the homologies of these organs. Hence I propose to use what I may call the

Clock-Face Notation to indicate these positions. As there are always *six* holobranchs arranged at equal intervals from one another, it will be clearly seen that, in a transverse section, the middle lines or axes of symmetry of the holobranchs must lie at the six angles of a regular hexagon inscribed in the circle which represents the transverse section of the branchial basket. Now, if we take the numerals 1 to 12 and place them in their ordinary positions on the clock-face, the mid-dorsal position will be represented by 12, the mid-ventral by 6, and the other numbers will lie at intervals of 30° along the circumference. In the *Simplex System* the positions of the six holobranchs will then be found to correspond with the numbers 2, 4, 6, 8, 10, 12. But in the *Duplex System* we shall find that the middle line, or axis of symmetry, of each holobranch (which, in this case, is actually the line lying midway between each pair of hemibranchs) lies in one of the positions 1, 3, 5, 7, 9, 11.

Now it happens that in all Odonate nymphs the six so-called "rectal glands" of the anal portion of the rectum lie in the positions 2, 4, 6, 8, 10, 12. Sadones, who only examined the gills of the larva of *Libellula depressa*, which belong to the *Duplex System*, noticed that their positions did not correspond with those of the "rectal glands." He therefore fell into the serious error of announcing that the rectal gills could not be homologous with these latter structures, since they did not correspond with them in position. It will be one of the main purposes of this paper to show that the six main longitudinal folds in the *Simplex System* are the homologues of the six "rectal glands," and also to explain how it is that the more complicated *Duplex System* has apparently shifted its position. Sadones's error shows, indeed, how dangerous it is for a biologist to study the complex mechanism of the very highest term in a phylogenetic series, without any reference to, or knowledge of, those less specialized forms that hold the key to the situation.

The *Tracheal System* of the gill-basket is physiologically an *efferent* system, and may be considered as such in proposing the nomenclature for its parts. It must not, however, be forgotten that it was originally an *afferent* system, and is developed as such in the embryo. The efferent function begins almost immediately after the hatching of the young larva. It will be found, perhaps, simpler to follow the ramifications of this system as if it were an *afferent* system, *i. e.* starting from the main longitudinal tracheal trunks, and following the branches into the gills. The names, however, which we shall propose, will be such as are suggestive of the efferent function.

Starting then either from the great dorsal or the visceral trunks, a series of large tracheal branches may be seen branching off to the gill-basket. There are six of these series altogether, corresponding to the six rows of gills. These tracheæ are the *primary efferent tracheæ* of the gill-basket.

Arrived close to the outer surface of the gill-basket, each *primary efferent*

trachea divides up into two large branches, the *secondary efferent tracheæ*. These enter the gill-basket in twelve separate rows. Their methods of branching now vary according to the particular type of gill-basket which they are to supply. Their branches may be spoken of generally as the *gill-efferents* or simply the *gill-tracheæ*.

These gill-tracheæ branch and re-branch again within the gill-folds until they finally give off a very large number of very minute tracheæ, which form the last term in this tracheal series. These are the *capillaries*, *capillary loops*, or *tracheal loops* of the gills, by means of which the oxygen is received from the circumambient water in the rectum into the gills themselves. Not one of these tiny capillaries ends blindly; every single one is a complete *loop*, as Oustalet has clearly shown.

Terminology of the Various Types of Gill.

Five principal types of gill will be recognized in this paper. Of these, two belong to the *Simplex System* and three to the *Duplex*. Subordinate types will also be recognized under one at least of these principal types.

In the *Simplex System*, the two principal types are:—

1. The *Undulate Type*, in which the free edge of the gill-fold is thrown into complicated undulations or waves. (Text-figure 2.)
2. The *Papillate Type*, in which all except the basal portion of the gill-fold is split up into numerous long slender papillæ, each of which carries an *axial trachea* from which the capillaries arise. (Text-figure 3.)

In the *Duplex System*, the three principal types are:—

3. The *Implicate Type*, corresponding fairly closely to 1 in the *Simplex System*. In each hemibranch the gills are folded and grooved in a complicated manner, and the two series forming each holobranch lie so that their curved distal borders come into close relationship alternately with one another, and tend to overlap. (Text-figure 5.)
4. The *Foliate Type*, in which the transverse gills forming each hemibranch appear in the form of separate leaves or foliæ.

Under this type we may distinguish two very different sub-types:—

- 4 a. The *Normal Foliate Type*, in which each folia is undulated along its free edge, and bears no papillæ. (Text-figures 6–7.)
- 4 b. The *Papillo-Foliate Type*, in which each folia is folded over into a kind of oval “hump,” bearing numerous tiny papillæ. These papillæ have no axial trachea, and only carry capillaries. (Contrast Type 2.) (Text-figure 9.)
5. The *Lamellate Type*, in which the gills forming each hemibranch appear as separate flat *lamellæ* or plates projecting into the rectum. (Text-figures 11–12.)

A considerable range of variation exists in the long series of forms which exhibit this type of gill. They do not, however, appear to be sufficiently distinct, or of sufficient importance, to warrant their elevation into the rank of sub-types of the same order as 4*a* and 4*b*, though I have suggested (p. 168) suitable names for them if it is desired to distinguish them in that way.

METHODS.

Three main methods of study have been followed, viz.:—

- (1) *The making of whole mounts of the branchial basket.*
- (2) *Photomicrography.*
- (3) *Microtomy.*

Whole Mounts.—Owing to the fact that the tracheæ in the gills collapse and lose their gaseous contents shortly after the death of the larva (usually in from one to two hours after death), it seemed at first that all attempts at making whole mounts must end in failure. However, after trying various methods without success, some very excellent results were obtained as follows:—

The larva was killed by being dropped into a tube of water in which a drop or two of chloroform had been well shaken up. It was then immediately dissected *under water*. The branchial basket, together with that part of the tracheal system surrounding it (including the main trunks), was dissected out, and opened up by a longitudinal cut near the mid-ventral line. It was then plunged at once into Carl's Fixative (see under *Microtomy*, p. 136), where it remained for 24 hours. After washing and dehydrating in the usual manner, it was passed into equal parts of absolute alcohol and cedar-oil for 24 hours, and thence into pure cedar-oil. There it remained for several days, during which time the gills darkened slightly. Finally, it was mounted on a slide within a raised ring, care being taken to remove as much cedar-oil as possible, so that the Canada Balsam should dry properly. The whole mount was then left for some weeks while it gradually darkened. The final result shows the gill-formation in yellowish-brown or orange, with the pigmented areas very strongly marked. The capillaries, of course, are not visible, as they have collapsed. But for a study of the *Simplex* or *Duplex System* in its entirety, these whole mounts are excellent. The drawings of portions of the gill-basket in the various systems (text-figs. 2, 5, 9, 11, 12) are taken from photographs of some of these mounts.

The everted gill-baskets are best mounted with their inner side uppermost, so that the whole gill-structure can be clearly seen. If it is desired to study the tracheal system, the slide may be turned carefully over and viewed from the back.

Photomicrography.—For this purpose the method followed previously by

Ris (23) was found to yield excellent results. The larva is killed in the manner shown above. As soon as it is dead, it is removed to a dissecting-dish and pinned *under water* with its ventral side uppermost. The dissection should not be made in glycerine or cedar-oil, since these highly refractive media are almost useless for the study of tracheal capillaries. The abdomen of the larva is opened by cutting away the projecting edges of the tergites and removing the sternites as a continuous ventral plate. The gill-basket can then be readily seen, lying in the posterior part of the abdomen. Next, the point of a pair of fine scissors is inserted into the posterior opening of the basket, and the latter is cut open longitudinally. This operation *everts* the gills, and the basket lies with its inner surface exposed. It is now easy to dissect out a complete holobranch. This should be placed on to a clean glass slide and floated out with a little water from a pipette. Having arranged it in a suitable position (*i. e.*, so as to obtain a good *lateral view* of it), a clean cover-glass should be allowed to descend lightly upon it. The gills are thus flattened out without being crushed or damaged, and the position of the tracheal capillaries is not disturbed. The gills may now be examined under a low or moderate power of the microscope, and a suitable portion selected for photography.

It is very necessary that the dissection, examination, and photographing of the gill should be completed within an hour or so of the death of the larva, because the air soon afterwards passes out of the capillaries, which then become invisible. There is no known method by which the air can be retained in these capillaries, so that permanent preparations can be obtained; and there is certainly no method that could yield results comparable to those obtainable by the method given, in which the capillaries stand out as black lines on a clear background.

The photomicrographic apparatus used was that of Reichert, Vienna, arranged in the vertical position. The photographs should be taken by transmitted artificial light (incandescent gas) on slow plates. With Ilford "Process" plates, which give excellent results, the exposure varies from fifteen seconds to four minutes, according to the magnification and the aperture of the iris diaphragm. In order to cover the plate it is best to use a No. 4 eyepiece. The most suitable objectives I found to be Nos. 1, 3, 6 *b*, and 8 *a*, giving magnifications of 30, 60, 320, and 560 diameters respectively with the closed tube. With the last-named objective a magnification of 725 diameters is obtainable by using the full length of the tube, and this can be extended to 850 diameters by lengthening the bellows of the camera. This last magnification is sufficient to show the complete structure of the smallest papillæ. One of the fine capillaries in a papilla of *Austrocordulia refracta*, Till., photographed at 850 diameters magnification, was found to measure barely 0.1 mm. in diameter. Its actual diameter in cross-section, therefore, would be about 0.12 μ .

Microtomy.—For this purpose two methods of procedure are available, both of which have their own peculiar advantages:—

1. The gill-basket may be dissected out as described above, and plunged at once into the fixative fluid. In the case of very complicated structures, such as the *Duplex System* of gill-basket in well-grown larvæ, some of the specimens should be dealt with by *everting* the basket with a longitudinal cut, so that the complicated foldings may be more widely separated.

2. The larva may be taken alive (preferably, soon after an ecdysis) and plunged into the fixative. By this means the fixative is drawn at once into the rectum by the movements of inspiration, and fixation of the rectum takes place from within.

The second method offers the advantage of studying the complete structure of the rectum in relation to the surrounding parts and body-wall. By it the very delicate rectal musculature is preserved entire, and the exact positions of the gill-eversions can be made out. But, before successful sectioning can be attempted, it is necessary to soften the chitinous integument of the larva, and this is a difficult task, if one would avoid any damage to the internal organs in consequence.

The first method enables us to proceed at once with dehydration and embedding, without the use of a softening process; but it only gives us, complete, the rectal structures enclosed within the circular muscle-layer. Hence it is advisable to obtain plenty of material and to use both methods, keeping the second only for use on larvæ which have just undergone ecdysis, and whose integument, in consequence, can be softened with the minimum of trouble.

Probably many methods of fixing, softening, and staining could be tried with success in the case before us. It seemed, however, advisable, bearing in mind the limited time at my disposal and the very great variety of material to be studied, to select one good method and to treat all the specimens alike. I therefore made use of the following method, previously applied in part by Carl and in full by Kurt-Bedau*, in studying the compound eyes of Insects:—

Fixation.—The fixative used was devised by Carl, and may be called Carl's Fixative. It consists of

Absolute alcohol	15 parts.	}
Concentrated formol	6 „	
Glacial acetic acid	2 „	
Distilled water	30 „	

The object should be left in this fixative for 24 hours, and then washed in 70 per cent. alcohol for 24 hours with several changes.

Softening.—If the second method of fixation, as given above, be used, the

* "Die Facettenauge der Wasserwanzen," Kurt-Bedau, Zeit. wiss. Zool., Bd. 97 (1910).

larva must now be placed for 24 hours or more (according to the state of hardness of the integument) in Soap Alcohol. This will extract all the fat, and occasionally causes local damage or malformation of a particular block of tissue; but it is a safe softening agent to use, provided it is not left in for too long a time. Hence the advice already given to soften only those larvæ which have recently undergone ecdysis. Soap Alcohol seems to me, in any case, preferable to Eau de Javelle.

Certain very tough larvæ, e.g. *Austrocordulia refracta*, seem to resist the softening treatment, even if immersed immediately after ecdysis. The integument of the larva is dark olive-green immediately after ecdysis, and hardens almost at once to a thick dark brownish state, which resists all attempts at softening within a reasonable time. In other larvæ the integument directly after ecdysis is very transparent and soft, and immersion in the soap alcohol need not be prolonged beyond a few hours.

The softening agent must be completely removed before dehydration by placing the larva again in 70 per cent. alcohol, and washing it in several changes extending over 24 hours or more. Before doing this, the abdomen should be cut off at about the 4th or 5th segment to allow of greater penetration on the part of the alcohol.

Dehydrating and Clearing.—The object should now be run up in the usual way through 90 per cent. alcohol (6 hours or less) to absolute alcohol (6 hours or less). It is then placed in a mixture of absolute alcohol and cedar-oil in equal parts for 24 hours. Finally, it is removed to pure cedar-oil and left there for 24 hours.

Infiltration and Embedding.—After clearing in cedar-oil, some finely sliced paraffin-wax of 36° M.P. (melting point) is introduced into the oil and allowed to dissolve. Enough should be added to make the mixture just pasty, so that, on warming ever so slightly, the fluidity returns again. The object is left thus for 24 hours. It is then placed in pure melted paraffin-wax of 36° M.P. for about 3 hours. From this it is passed into melted wax of 52° M.P. for a further 3 hours. Two or three changes may be given during each three hours in order to ensure the removal of all the cedar-oil. Finally, the object may be embedded in paraffin of 58° M.P. straight from the melted 52° M.P. wax; or, if the weather be warm, a further short period in melted wax of 58° M.P. may be given before the final embedding.

Sectioning.—As most of the gill-baskets are fairly large objects the majority of sections should be cut at 12 or 15 μ , the thickness being reduced to 5 or 7 μ at any desired level through a number of sections, in order to provide material for finer histological studies.

In the case of the whole larva the cutting should begin at the anal end, so that the rectum is reached as quickly as possible. The anal appendages can, of course, be removed with scissors before the softening process is begun—or after it, if preferred.

Double Embedding.—The ordinary single embedding method yields very satisfactory results in nearly all cases. For the papillate types, and whenever a very exhaustive histological analysis is required, celloidin embedding may be carried out from the pure cedar-oil stage as follows:—The object is embedded in celloidin in the usual manner, but with 1 part of cedar-oil added to 4 parts of the celloidin solution. On reaching the strongest celloidin solution the proportion of cedar-oil is reduced to 1 part in 5. The hardening is done in 5 parts of chloroform to 1 part of cedar-oil, the mixture being frequently changed. The block must then be embedded in paraffin dissolved in benzol to concentration in a closed vessel. The benzol must be allowed to evaporate very slowly for a week or more, until the paraffin is quite dry and firm. Sections may then be cut from the block as fine as 3 μ in thickness. The method is, however, not only a very protracted one, but offers considerable difficulties, especially in the successful elimination of the benzol.

MATERIAL STUDIED.

Nineteen species, belonging to fifteen genera, have been studied for the purpose of this paper. Microphotographs were taken of the gills of each of the nineteen species, and sets of serial sections prepared from the rectum of every genus represented. In some genera sections were obtained not only from the more advanced larval instars, but also from the earlier stages (first to eighth instars). The total number of sets of serial sections prepared and studied amounted to over seventy.

In the following table I have arranged the material studied in the accepted systematic order, giving family, subfamily, and tribe, together with columns indicating the system and type of gill to which each genus belongs:—

Family.	Subfamily.	Tribe.	Genus.	Species.	System.	Type.	
ÆSCHNIDÆ.	PETALURINÆ ...		<i>Petalura</i>	<i>P. gigantea</i> , Leach.	Simplex.	Undulate.	
	GOMPHINÆ	Gomphini	<i>Austrogomphus</i> ...	<i>A. ochraceus</i> , Selys.	"	"	
			<i>Hemigomphus</i> ...	<i>H. heteroclitus</i> , Selys.	"	Papillate.	
	ÆSCHNINÆ ...	Brachytronini .	<i>Dendroæschna</i> ...	<i>D. conspersa</i> , Till.	Duplex.	Implicate.	
			<i>Austrophlebia</i> ...	<i>A. costalis</i> , Till.	"	"	
			<i>Austroæschna</i> ...	<i>A. multipunctata</i> , Martin.	"	"	
		Æschnini	<i>Æschna</i>	<i>Æ. brevistyla</i> , Ramb.	"	Foliate.	
			<i>Anax</i>	<i>A. papuensis</i> , Burm.	"	"	
	LIBELLULIDÆ.	CORDULINÆ...	Synthemini ...	<i>Synthemis</i>	<i>S. macrostigma</i> , Selys.	Duplex.	Lamellate.
			Idocorduliini	<i>Metathemis</i>	<i>S. eustalacta</i> , Burm.	"	"
<i>Austrocordulia</i> ...				<i>M. guttata</i> , Selys.	"	"	
Eucorduliini ...			<i>Hemicordulia</i> .	<i>A. refracta</i> , Till.	"	"	
			<i>Cordulephya</i>	<i>H. taru</i> , Selys.	"	"	
LIBELLULINÆ .		Libellulini	<i>H. australiæ</i> , Ramb.	<i>H. australiæ</i> , Ramb.	"	"	
			<i>Cordulephya</i>	<i>C. pygmæa</i> , Selys.	"	"	
		Sympetrini	<i>Orthetrum</i>	<i>O. caledonicum</i> , Br.	"	"	
			<i>Diplacodes</i>	<i>O. villosovittatum</i> , Br.	"	"	
				<i>D. hæmatodes</i> , Burm.	"	"	
			<i>D. bipunctata</i> , Br.	"	"		

It will be noticed that a single type of gill, and that the most highly specialized of all, characterizes the whole of the Libellulidæ, while the other four types are distributed in a definite phylogenetic sequence within the Æschnidæ.

GENERAL STUDY OF THE BRANCHIAL BASKET.

A. *Its Position within the Abdomen.*

Longitudinal Extent.—When contracted the branchial basket occupies the whole length of segments 7 and 8, together with a small part of the posterior end of 6 and of the anterior end of 9. When expanded the gill-folds can be seen to reach forward as far as the middle of 6, or even a little further, and backwards nearly to the posterior end of 9. In length the gill-basket occupies three-fourths or more of the whole extent of the rectal region.

Position in Transverse Section (text-fig. 1).—The gill-basket, as seen in transverse sections of the abdomen, occupies a large, roughly circular space in the middle, surrounded by the hæmocoelæ. Dorsal to it lies the heart (*ht*), and immediately ventral to it is the ventral nerve-cord (*vg*). On either side it is flanked by the fat-body (*fb*) and a mass of tracheæ. Of these, the two large dorsal trunks (*dt*) lie dorso-laterally on either side, close to the gill-basket, while the smaller visceral trunks (*vst*) lie similarly ventro-laterally. Both dorsal and visceral trunks give off numerous branches, which enter the gill-basket. Each dorsal trunk gives off two sets of branches, each visceral trunk only one. The arrangement of these branches is discussed below (p. 181). The ventral trunks (*vnt*) lie at about the same level as the visceral trunks, but further apart, and send no branches to the gill-basket.

In the hæmocoelæ, between dorsal and visceral trunks, there may usually be seen two or three Malpighian tubules (*mlp*) running backwards from their point of origin at the anterior end of the proctodæal part of the intestine. Most of these tubules, however, lie well forward from the level of the gill-basket.

The other structures to be noted in a cross-section through the abdomen at this level are the large masses of the *segmental muscles*. These consist of dorsal or tergal longitudinal muscles (*mld*), ventral or sternal longitudinal muscles (*mlv*), and the smaller masses of the dorso-ventral or tergo-sternal transverse muscles (*mt*) occupying the angular spaces near the junction of the tergite with the sternite.

B. *Its Supports.*

The gill-basket, being part of the continuous alimentary tube, has no special supports of its own, unless its weak muscular tunic can be considered as such. But, just posterior to the gill-basket, and, in the later larval stages, also connected with the narrower posterior end of the basket itself, there can

be seen *six radial strands* of muscle arising in the folds of the thin epithelium separating the so-called "rectal glands," and passing out across the hæmocœle to become attached to the body-wall. These are the *dilatator muscles* of the rectum. They not only serve in a sense as actual supports for suspending the posterior part of the rectum firmly in the hæmocœle, but, by their contractions, cause the rectum to expand, and thus allow of the entry of water through the rectal valves into the gill-basket.

In the later larval stages the presence of these muscles gives the posterior portion of the gill-basket a characteristic hexagonal shape in cross-section. Further forward this effect is not noticeable, the usual shape of the basket being nearly circular or slightly compressed dorso-ventrally.

Using the clock-face notation, the positions of the insertions of the dilatator muscles are 1, 3, 5, 7, 9, 11. The positions of the rectal glands are 2, 4, 6, 8, 10, 12. These facts are of great importance when we come to the discussion of the homologies of the rectal gills.

C. Its General Structure.

All the gill-baskets of Anisopterid larvæ show the following general structure :—

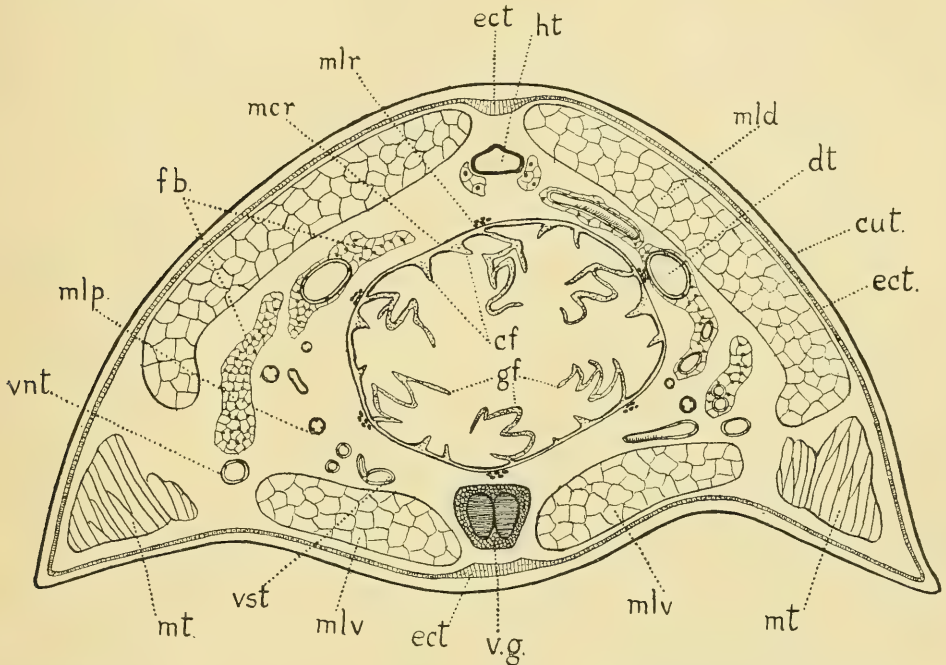
Passing from within outwards we meet first with a fine *cuticle* or *chitinous intima*. External to this is the *rectal epithelium*, from which the cuticle is derived. Surrounding the epithelium is an almost continuous layer of *circular muscle-fibres* only one row thick, with numerous openings for the entry of the tracheæ into the gill-basket. Finally, external to this, we can recognise a layer of longitudinal muscles, not forming a tunic, but segregated into six rather weak *longitudinal bands*, each formed of a small number of separate fibres. These are placed in the positions 2, 4, 6, 8, 10, 12 of the clock-face.

The Cuticle.—This is a very fine, transparent, non-cellular, non-staining layer which covers the internal face of the rectal epithelium throughout. It is absolutely smooth and structureless except along the edges of the gill-folds, where it is usually armed with a series of tiny chitinous teeth. It is secreted by the rectal epithelium, and is cast off at each ecdysis. It is exactly comparable with the similar fine internal cuticle which lines internally the stomatodæal portions of the alimentary canal.

The cuticle forms the outer covering of such organs as the papillæ and tubercles of the gills, when these are developed. In such cases it may develop a special armature of strong spines or of transverse chitinous rods, which will be described under the study of those types of gill in which it occurs.

The Rectal Epithelium.—This is remarkable in showing, throughout the gill-basket, no trace whatever of separate cell-divisions. It is, in fact, a

nucleated syncytium, and must be regarded as a highly specialized structure derived from an originally typical proctodæal epithelium with separate cell-boundaries. Except at certain definite places, where it swells up into the thick turgid structures known as the *basal pads*, this syncytium is a flat pavement-like layer containing numerous nuclei at fairly regular intervals. In some forms it is entirely unpigmented throughout; in others, especially at certain places, dense masses of pigment-granules are present and hide the nuclei from view.



TEXT-FIG. 1.—Transverse section through seventh abdominal segment of the larva of *Eschna brevistyla*, Ramb., 4th instar, to show position and structure of gill-basket. ($\times 32$.)

cf, cross-fold; *cut*, cuticle; *dt*, dorsal tracheal trunk; *ect*, ectoderm; *fb*, fat-body; *gf*, main gill-fold; *ht*, dorsal vessel or heart; *mcr*, circular muscle-layer of gill-basket; *mld*, dorsal longitudinal segmental muscle; *mlp*, Malpighian tubule; *mlr*, longitudinal muscle-band of gill-basket; *mlv*, ventral longitudinal segmental muscle; *mt*, transverse segmental muscle; *vg*, ganglion of ventral nerve-cord; *vnt*, ventral tracheal trunk; *vst*, visceral tracheal trunk.

The protoplasm of this syncytium is only very slightly chromatophil, giving only a light purplish stain after long immersion in hæmatoxylin. The nuclei, on the other hand, are very receptive to the same stain. They are of moderate size, usually rather oval, showing granular contents without any distinct nucleolus.

At regular intervals the rectal epithelium of the gill-basket is evaginated into the interior to form one of the *gill-folds*. Their position and extent vary in the different types of gill-basket; but the structure of every type of fold is essentially the same. The two walls of the evagination come into close apposition over their whole extent, except for a comparatively small basal portion, where they remain separate, enclosing a small space in which the *hypobranchial tissue* is developed, and into which the efferent or gill-tracheæ pass from the exterior (Plate 22. figs. 25-27). The fine tracheal branches or capillaries of the gill-fold are supported in the syncytium of one wall or the other. Throughout the distal portion of the gill, where the syncytia of the two walls fuse completely, the tracheal capillaries are seen to lie in the fused mass, but usually slightly nearer to one side than to the other. Owing to the great rapidity with which the air passes out from the capillaries after the death of the larva (no trace of air can be detected therein two to three hours after death) and to the absence of any spiral thread in these tiny tracheoles, it is seldom that one can make out the lumen of any of the capillaries in cross-section. But one finds, throughout the slender distal portion of the gill-folds, in addition to the already-mentioned nuclei of the epithelial matrix, a large number of tiny nuclei of very characteristic structure, which are undoubtedly the nuclei of the tracheal capillaries, since they correspond very closely to the nuclei lying in the matrix of the larger tracheæ. They are small, usually rounded, and stain deeply with hæmatoxylin, so that no very definite nuclear structure can be made out in them. Frequently one notices a tiny clear space attached to one side of one of these nuclei. This appears to me to represent the collapsed lumen of the capillary vessel. Other small bodies noticeable in the syncytium of the distal portion of the gill, but not present in the gills of all forms examined, are small pigment-granules and tiny transparent globules of a highly refractive nature, probably composed of fat.

The basal portion of each gill-fold, as has been already stated, broadens out so that a space of greater or less extent is formed between the two walls. Here the epithelium either of the anterior of the two walls, or of both, may be broadened out into the form of a thickened *basal pad*. As these structures vary much in shape and position, as well as in actual size and thickness, I have postponed a general discussion of them until after the various types of gill have been described (see p. 170). For the same reason I shall here only mention the presence, in the space between the walls at the base of a gill, of a peculiar mass of tissue whose origin and functions seem to be rather doubtful. This is the tissue called by Chun and Faussek *connective tissue*, by Sadones *adipose tissue*. As both these names are admittedly unsuitable, I propose here for it the name *hypobranchial tissue*. We may then define the hypobranchial tissue of the gill-basket of Anisoptera larvæ as the mass of tissue lying in the basal space between the two walls of the gill-fold, and

carrying in its meshes the efferent trachea and its main branches for that particular portion of the gill-fold under consideration. Generally speaking, the *hypobranchial tissue* is flanked on one or both sides by the basal pad, from which it is easily distinguished at once by its different structure, nuclei, and staining qualities (see p. 176).

The Circular Muscle Tunic.—The outstanding feature of the circular muscle-layer of the gill-basket is its weakness. It is everywhere composed of only one row of fibres, which run closely parallel around the basket so as to form a complete investment, except for numerous spaces left for the tracheæ to pass through (text-fig. 1, *mc*r). The weakness of this tunic precludes the supposition that it is of use in the contraction or expansion of the gill-basket. These movements appear to be caused by the movements of the segmental muscles of the abdomen, and in particular by the six *radial* muscles already mentioned.

The Longitudinal Muscle-Bands.—In the young larva each longitudinal band is seen to be composed only of five or six strands of muscle-fibre placed fairly close together so as to form a definite band (text-fig. 1, *ml*r). In more mature larvæ a larger number of fibres is present, and the longitudinal bands become very definite structures. They do not seem, however, to be of much strength considering the size of the gill-basket. They aid, by their contractions, the shortening of that organ which takes place regularly during the act of rectal breathing; but their function can only be regarded as auxiliary to that of the far more powerful segmental muscles of the abdomen.

STUDY OF GILL-TYPES.

A. SIMPLEX SYSTEM.

Definition.—The *Simplex System* of gills consists of six holobranchs in the positions 2, 4, 6, 8, 10, 12 of the clock-face. Each holobranch is a continuous longitudinal eversion of the rectal wall, supported to right and left alternately by numerous small *cross-folds*, these latter lying in a slanting direction nearly transverse to the main fold, and not projecting far into the rectal cavity.

The Tracheal Supply.—We have already mentioned that each *primary efferent trachea* divides into two *secondary efferent tracheæ* before reaching the branchial basket. Thus there are *twelve sets* of *secondary efferent tracheæ* entering the basket from outside. There are also *twelve sets* of cross-folds, viz., one set to right and one set to left of each main longitudinal fold. Now these cross-folds lie below the courses of the secondary tracheæ—in fact, each cross-fold is developed in relation to a single secondary trachea, which sends out branches and capillaries into it. Each secondary trachea, however, continues inwards in a slanting direction until it reaches a main longitudinal fold, into which it gives off branches and, finally, capillaries.

In order to understand the somewhat complicated manner in which the tracheæ are distributed, let us look at the diagram in Plate 22. fig. 22. We see from this that the *primary* efferent tracheæ approach the circumference of the gill-basket at the positions 1, 3, 5, 7, 9, 11 on the clock-face, though the main gill-folds, as already stated, lie in the positions 2, 4, 6, 8, 10, 12. The *secondary* efferent tracheæ, formed by the bifurcation of any given primary trachea, enter the basket therefore slightly to right and left of one of the positions represented by an *odd* number on the clock-face. Nor do the two secondary tracheæ from any given primary trachea enter at the same *transverse* level—one is always a little in front of the other. This is shown in the diagram by representing these tracheæ by alternate complete and dotted lines, the dotted ones not being at the same level as the complete ones.

After giving off branches to the cross-folds, the secondary tracheæ run on to enter the main folds at their bases. This they do by branching into a series of gill-tracheæ, which spread out at different levels, and then bend sharply inwards to enter the main folds. Each series of gill-tracheæ forms a small *fan* or pencil of rays, and enters the main fold at a convexity, or crest, of the undulations of its base-line.

It follows from this that each main longitudinal fold receives tracheæ from two sources which supply it alternately, viz., a series entering from the right and one from the left. In the case of the mid-dorsal longitudinal gill-fold (position 12) the series to the right is a set of gill-tracheæ given off by the series of secondary efferent tracheæ which form the more dorsal or left-hand branchings of the upper series of primary efferents given off by the *right* longitudinal dorsal tracheal trunk; while the series to the left is derived correspondingly from the upper series of primary efferents given off by the left dorsal trunk. Thus the gill in position 12 receives its tracheæ alternately from the positions 1 and 11, or thereabouts. A similar arrangement holds for each of the other five main gill-folds.

The main longitudinal gill-folds are older, both phylogenetically and ontogenetically, than the cross-folds (see p. 187), and are the only gills present in the rectum in the newly-hatched larva.

The cross-folds are never very large, nor do they project far into the rectum. They are always very crumpled and irregular. As they are well supplied with tracheæ, they certainly aid in respiration. Probably the twelve sets of cross-folds taken together scarcely extract more than 50 per cent. of the amount of oxygen extracted by the six main folds in the same period of time.

The principal interest of the cross-folds is their relationship to the gills in the *Duplex System*, to be dealt with later (p. 150).

We shall now turn to the study of the two types of gill known to exist, which belong to the *Simplex System*. These are (1) the *Undulate Type*,

(2) the *Papillate Type*. A careful study of these two types will give us a much clearer idea of what the *Simplex System* is really like.

1. **Undulate Type.** (Text-fig. 2 ; Plate 18. fig. 1 ; Plate 21. fig. 17 ; Plate 22. figs. 22, 25.)

This type has been found by me in the gills of *Petalura* and *Austrogomphus* (text-fig. 2). Dr. Ris has also found it in *Cordulegaster*. It therefore occurs just in those genera which are already acknowledged, from a study of other characteristics, to be the most archaic of living Anisopterid dragonflies. The principal characteristics of the type is that each main



TEXT-FIG. 2.—*Austrogomphus ochraceus*, Selys.

Posterior portions of three holobranchs from the everted gill-basket of a full-grown larva. *Undulate Type*. Semi-diagrammatic, drawn from a whole mount. ($\times 30$.)

longitudinal gill-fold is thrown into fairly regular folds or undulations. These folds do not stand directly out into the rectal cavity, normal to the circumference, but slant away posteriad, and lie so close to one another that they give the appearance of a somewhat complicated frill with its folds all running towards the posterior end of the rectum (text-fig. 2).

The cross-folds are of the same folded or undulate type, but much less prominent, and appear to be more crumpled and irregular. Their position in relation to the main folds is well shown in text-fig. 2.

Along the free borders of the folds the cuticle carries a series of tiny chitinous hooks placed at wide intervals apart and directed backwards. These are scarcely visible at all in *Austrogomphus*, but can be clearly made out in *Petalura* under a high power.

Arrangement of the Tracheæ in the Gill.

Plate 18. fig. 1 shows the arrangement of the tracheæ in a portion of a main longitudinal gill-fold of *Austrogomphus ochraceus*, which, previous to being photographed, had been smoothed out almost into one plane by means of a camel's-hair brush. The gill-tracheæ leave the secondary efferents along the line of the base of the gill a little to left and right of it alternately. Each undulation is usually supplied by four or five of these gill-tracheæ, which are of gross calibre run far up into the gill-fold, their distal ends reaching fairly close up to the free edge of the fold. From each gill-trachea short side-branches are given off, most abundantly towards its distal end. These branches quickly break up into tufts or bundles of capillaries, which also seem to be most numerous towards the distal ends of the gill-tracheæ. The capillaries diverge as they leave the branches, and spread out all over the gill-fold, running slantwise at all angles towards the free edge of the gill. Here they all turn over in *complete loops*. It is possible under a high power, by careful manipulation of the fine adjustment, to follow the course of a single capillary, and to note two interesting facts in connection with it. First, those capillaries which arise near the distal end of a gill-trachea, after forming their loops, run back to enter branches of an adjoining gill-trachea which are situated more proximally to the gill-base. Secondly, those capillaries which arise so as to run along one gill-wall, after forming their loops, descend along the opposite gill-wall. As the two gill-walls are in very close apposition, this change of position can only be accurately judged by the use of the fine adjustment. By examining the free edge of the gill-fold in Plate 18. fig. 1, about the middle of the picture, both the above conditions can be made out fairly well.

In the cross-folds, the gill-tracheæ, short branches, and capillaries are very similar to those in the main folds, but the gill-tracheæ are shorter, and do not extend so far into them. They are thus mainly filled with capillaries which arise and end more at the same level than do those in the main fold. In Plate 18. fig. 1, three cross-folds can be seen flattened down below the main fold, while portions of two intermediate cross-folds lying above the main fold can also be made out.

Number of Capillaries in the Gill-basket.

In *Austrogomphus ochraceus* I estimate the number of complete loops belonging to each secondary efferent trachea at 100 or over. There are 6 longitudinal main folds, each of which is thrown into about 12 principal undulations, each of which receives approximately the whole of the capillaries from one secondary efferent trachea and its branches. Thus we get a total of $100 \times 6 \times 12$, or 7200 complete capillary loops for the six main folds. Allowing a total of 50 per cent. extra capillaries for the twelve

sets of cross-folds, whose total area probably does not exceed one-half of the total area of the six main folds, we thus obtain an approximate total of 10,800 complete capillary loops in the whole gill-basket.

In *Petalura gigantea*, a larva which is many times larger than that of *Austrogomphus ochraceus*, the gill-tracheæ are not only much shorter, but more numerous. As the only larvæ available for examination had been preserved for four years in alcohol, none of the capillaries were visible, and it was therefore, of course, quite impossible to attempt an estimate of the number of finer capillaries. We should, I think, be well under the estimate in assigning a total of 20,000 complete loops to this large larva, which even then would be poorly supplied in comparison with the much smaller *Austrogomphus* larva, after making due allowance for its much greater size.

In *Cordulegaster*, the gill-folds resemble those of *Petalura* very closely in the thickness and arrangement of the efferent trachea and the firmness of the cuticle.

The occurrence of the *Undulate Type* in *Austrogomphus* is very remarkable, since all other *Gomphine* whose larvæ have so far been examined have been found to possess the *papillate* type of gill. The discovery of this important difference, then, suggests that the genus *Austrogomphus* is not closely related to any of the Palearctic genera, and is very probably an isolated remnant of an even older Gomphine fauna.

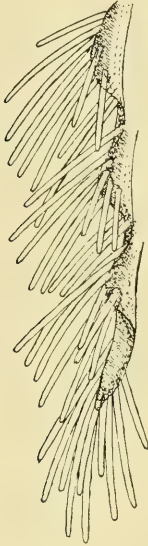
It should, however, be borne in mind that none of the larvæ of the larger *Gomphine* of the tribe *Ictini* have yet been studied in this connection. In these larger, less reduced, and presumably more archaic genera, we may well hazard the supposition that some at least, if not all of them, will be found to possess the more primitive *undulate type* of gill.

2. Papillate Type. (Text-fig. 3 ; Plate 18. fig. 2.)

This type of gill has been found by me only in the larva of *Hemigomphus heteroclitus* (text-fig. 3). Dr. Ris has shown it to exist also in the larvæ of the Palearctic Gomphine genera *Gomphus* and *Onychogomphus*. It seems to be characteristic of the main mass of the *Gomphine*—or, at any rate, of the tribe *Gomphini*.

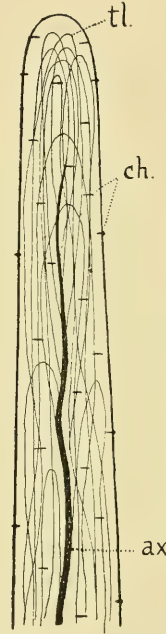
As in the *Undulate Type* of gill-basket, each of the six main folds is a complete longitudinal eversion of the rectal wall, with supporting cross-folds arranged in the same manner. But, in the present case, these complete eversions of the wall only project a very short distance into the cavity, and carry along their distal border a very conspicuous layer of dark purplish-brown pigment. Below this layer of pigment each gill-trachea is found to split up into a set of five or six branches. Each of these branches projects *through* the pigment-layer, carrying with it the wall of the rectum, so as to form a long slender papilla of cylindrical form, projecting far into the

rectum, and having the tracheal branch as a kind of axis within it. These branches of the gill-tracheæ will be called the *axial* or *papillar tracheæ* (text-fig. 4, *ax*). The papillæ, though actually arising thus in groups of five or six, each group corresponding to a single "wave" in the original undulate type, are so numerous and closely set as to appear like a continuous series. The papillæ are developed, not only along the course of the main gill-folds, but also along the cross-folds. Hence, on opening the gill-basket longitudinally, one sees a mass of papillæ of an intense shining whiteness, projecting apparently from all points of the surface.



TEXT-FIG. 3.—*Hemigomphus heteroclitus*, Selys.

Posterior portion of a main fold from the everted gill-basket of a nearly full-grown larva, viewed somewhat in profile. Cross-folds omitted. *Papillate Type*. Semi-diagrammatic, drawn from the freshly opened gill-basket. ($\times 30$.)



TEXT-FIG. 4.—*Hemigomphus heteroclitus*, Selys.

Anterior portion (about one-fourth) of a papilla from the same larva. ($\times 600$.) *ax*, axial or papillar trachea; *ch*, chitinous rods; *tl*, loops of tracheal capillaries.

Structure of the Papillæ.—Each papilla consists of a simple finger-like eversion of the wall of the gill-fold, containing no pigment. Its chitinous cuticle, when examined under a high power, is seen to be beset with numerous short transverse chitinous rods, which give it a finely ribbed appearance (text-fig. 4, *ch*). The use of these little chitinous projections seems to be to prevent the papillæ from clinging together, and thus to

ensure a complete circulation of aerated water around each single one of them. [Compare the function of the tubercles found on the lamellæ of Libellulidæ, for which see p. 162.]

Arrangement of the Tracheæ.—We have already shown how the separate gill-tracheæ divide each into five or six *axial* or *papillar tracheæ*, each of which then forms the axis of a separate papilla. The *capillaries* are almost entirely confined to the papillæ, only a few stray ones being detectable here and there in the pigment-layer. Very possibly these may have become displaced or pulled out from the bases of papillæ during the process of dissection. The capillaries arise along the whole course of the papillar trachea. They are of excessive fineness, and can only be clearly detected under a high power (text-fig. 4, *tl*). They run almost parallel to the main axis of the papilla. But, whereas the papillar trachea itself does not reach the extreme tip of the papilla, all the capillaries, on the other hand, run right up to the very tip, where they curve sharply over in small loops and run back to rejoin the papillar trachea near its distal end.

In the everted gill-basket, the papillæ are seen to project in a slanting position directed somewhat posteriorly. The angle between the papillar axes and the longitudinal axis of the gill-fold varies between 130° and 140° , being greatest at the posterior end of the gill-basket, where it terminates in a series of long papillæ projecting beyond the end of the basal fold.

Origin of the Papillate Type.—The type seems to have been called forth in the course of evolution by the assumption of peculiar habits on the part of the larva. Whereas the larvæ of the genus *Austrogomphus* all live on the river-bottoms, hidden in loose débris, or buried only partially so that their heads and anal ends project freely into the water, the larvæ of *Hemigomphus*, on the other hand, *bury themselves completely in pure sand* well below the surface of the river-bed. In this they burrow or remain motionless all day, only emerging at night to look for food. The anal opening is protected, as in *Petalura*, not only by valves, but by crossed hairs, which allow of the inspiration of water from the damp sand, while keeping the sand itself out. When the larva is buried in the sand, the process of respiration must necessarily be very slow, so that it is of the utmost importance that the larva should command the most efficient and complete extraction of oxygen from the small quantity of available water. This objective is certainly marvellously well ensured by the papillate type of gill, which can be easily seen to have two very distinct advantages over the undulate type:—

1. As a result of the splitting-up of the gill-tracheæ, a very much greater number of capillaries is developed.

2. As the capillaries lie in groups isolated in separate papillæ projecting far into the rectal cavity, their ability to absorb oxygen is very much increased, especially as the water bathes each papilla on all sides, whereas in the undulate type it can only course along the two sides of each fold.

Number of Capillaries in the Gill-basket.

It is not easy to estimate the number of capillaries in a papilla. They are sufficiently numerous to give a *striated* appearance to the papilla; but the diameter of the latter is very narrow, and hence I have placed the minimum number at 20 complete loops. There are about 100 papillæ developed along a single longitudinal fold in *Hemigomphus*. Hence we get a total of $6 \times 100 \times 20$, or 12,000 complete loops for the six folds. Adding 50 per cent. for the cross-folds, we obtain a total of 18,000 loops as a conservative estimate. This is a great increase in the number estimated for *Austrogomphus* (10,800), especially as the larvæ of *Hemigomphus* examined were not full-grown and were of smaller size than those of *Austrogomphus*.

Considering that it belongs to the *Simplex System*, the papillate type must be given a very high place in the development series for the remarkable level of efficiency attained by it. Judging also by other attempts made in the course of evolution to develop papillæ on much more highly developed gill-folds of the *Duplex System*, we must regard these devices as being amongst the most efficacious yet evolved for the extraction of oxygen from the surrounding water.

B. DUPLEX SYSTEM.

Definition.—The *Duplex System* of gills consists of six double holobranchs whose middle lines or axes of symmetry lie in the positions 1, 3, 5, 7, 9, 11 of the clock-face. Each holobranch consists of two hemibranchs possessing a tracheal supply derived from a single series of primary efferents. Each hemibranch consists of a series of separate gills arranged in a direction more or less transverse to the middle axis of the holobranch, and corresponding, in position and development, with the series of cross-folds already mentioned in the *Simplex System*. Main longitudinal folds, of the type and position defined in the *Simplex System*, are either completely absent, or, if present, are aborted and do not carry tracheæ.

The Tracheal Supply.—Although the Duplex System seems at first sight to be so much more complicated than the Simplex, yet its tracheal supply is much more easily understood. For, with the elimination of the main longitudinal folds, the Duplex System may be seen to resemble the *cross-folds alone* of the Simplex System. Thus, then, each series of primary efferent tracheæ (approaching the gill-basket at the positions 1, 3, 5, 7, 9, 11 of the clock-face, respectively) supplies a complete holobranch in a corresponding position. When a primary efferent bifurcates, one branch, or secondary efferent, goes to one hemibranch, the other to the other. So, then, each of the twelve hemibranchs is completely supplied by tracheæ from a single complete series of secondary efferents.

To give an example:—The more dorsal, or left-hand hemibranch of the

holobranch in position 1 is supplied by the more dorsal or left-hand series of secondary efferents arising from the upper set of primary efferents given off by the right dorsal longitudinal tracheal trunk.

The diagrams in Plate 22, figs. 23, 24, show the method of tracheal supply, and should be carefully compared with that for the Simplex System (Plate 22, fig. 22).

We shall now turn to the study of the three main types of gill into which the Duplex System may be divided, viz. (1) the *Implicate*, (2) the *Foliate*, and (3) the *Lamellate*.

1. **Implicate Type.** (Text-fig. 5 ; Plate 18, figs. 3, 4 ; Plate 21, fig. 18.)

This type of gill has been found by me in larvæ of the genera *Dendroæschna*, *Austrophlebia*, and *Austroæschna*. Dr. Ris has also found it in the Palæarctic genus *Brachytron*. All these genera belong to the tribe *Brachytronini* of the subfamily *Æschnini*. Hence we may fairly claim the Implicate Type as characteristic of, and peculiar to, this tribe of dragonflies.



TEXT-FIG. 5.—*Austroæschna multipunctata*, Martin.

Posterior two-thirds of three hemibranchs from the everted gill-basket of a full-grown larva. *Implicate Type*. Semi-diagrammatic, drawn from a whole mount. ($\times 30$.)

The Implicate Type may be said to correspond, in the Duplex System, to the Undulate Type in the Simplex System. That is to say, the two types show, in the method of distribution of the capillaries and finer tracheal branches, a very close similarity. This may be seen by comparing Plate 18, figs. 1 and 3, in both of which portions of the gills have been smoothed out by means of a camel's-hair brush before being photographed. However, in the broader aspects of structure and development, the two systems are very distinct. The Implicate Type may be easily understood as a derivative of the Undulate Type by the suppression of the main longitudinal gill-folds in the latter, and the upgrowth of the small cross-folds to project far into the rectum, so as to form the six pairs of hemibranchs of the Implicate System—these cross-folds still retaining their undulate characteristics, but taking on a special shape and arrangement of their own. The complicated formation resulting from this may be well studied in text-fig. 5. From this figure it will be seen that each separate gill projects from its base-

11*

line in a slanting direction, so that its rounded and free distal end comes to overlap a corresponding gill from the next consecutive hemibranch situated slightly more posteriad. The two sets of overlapping gills belong to one complete holobranch. Further, each gill is in the form of an elongate-oval leaf on a broad base, with its upper surface very concave, giving it almost a grooved appearance. Also, the free border of each leaf is waved or undulated, sometimes only moderately as in *Austroæschna*, sometimes very deeply as in *Dendroæschna*. In the latter case, the complicated appearance of the newly everted gill-basket almost defies description.

Dr. Ris's short account of the gills in *Brachytron* show that they resemble very closely those of *Austroæschna*. He says that they are "leaves which project like tiles one over another" ("Blätter, die sich dachziegelförmig überlagern").

There are some important differences to be noted in the gills of the four genera here under consideration. In *Dendroæschna* and *Austrophlebia* there is no sign either of fat-globules or of pigment, and the whole apparatus is of a pure shining white colour. The frills along the free borders of the gills are very numerous and complicated, especially in *Dendroæschna*, where the whole gill-formation resembles nothing so much as a turbulent sea of waves and wavelets inextricably intermingled. Transverse sections of the rectum of this larva reveal the almost unbelievable extent to which this complex folding and frilling is carried.

In the genera *Austroæschna* and *Brachytron* there is no complicated frilling of the edges of the gills. They are, instead, fairly regularly waved and undulated. There is a considerable amount of pigmentation of a purplish-brown colour.

It is interesting to note that in the genus *Austroæschna* there is a distinct tendency shown, in the posterior region of the gill-basket, towards a constriction of the broad bases of the gills. Thus the gills in this part of the rectum tend to approach the *Foliate Type* as developed in the genus *Æschna* (p. 153). If we now also bear in mind the fact that it is just in this posterior region of the gill-basket, in *Æschna* itself, where the gill-foliæ are most widely separated off and most definitely developed, we may well claim to have here definite evidence that the earliest form of *Implicate Type* gave origin to the *Foliate Type* during the course of evolution.

Arrangement of the Tracheæ.—Each separate gill is supplied by a strong thick secondary efferent trachea, which approaches its base from the side nearest to the middle line of the holobranch to which it belongs. This secondary efferent bends sharply down into the base of the gill, branching into several stout gill-tracheæ. These run straight up towards the distal border of the gill, giving off numerous capillaries and also smaller branches which also quickly break up into capillaries. The structure of the free border and the arrangement of the capillaries resemble very closely those

of the *Undulate Type* of gill. The capillaries are very numerous and vary somewhat in fineness. In *Austroæschna* and *Brachytron* they seem to be much of the same calibre as in *Cordulegaster*, but in *Dendroæschna* and *Austrophlebia* they are of excessive fineness and very difficult to photograph. In these genera, too, there is a more extensive branching of the gill-tracheæ, so that each "frill" is supplied more or less completely with capillaries thrown out from a single branch.

Number of Capillaries in the Gill-basket.

In *Austroæschna* we should assign about 200 complete capillary loops to each secondary efferent trachea (inclusive of its large branches). Each hemibranch receives, on an average, 12 of these sets. Hence the total number of complete loops is $12 \times 12 \times 200$, or 28,800.

In *Dendroæschna*, it is almost impossible to attempt an approximation. Each "frill" must carry a minimum of at least 20 loops. The edge of each groove or plication carries 16 or more "frills," and there are 12 grooves to a hemibranch. Thus we get a total of $12 \times 12 \times 20 \times 16$, or 46,080 complete loops in the gill-basket! The much larger larva of *Austrophlebia* probably contains an even greater total. The very great increase in the number of loops in these genera, compared with *Austroæschna* and *Brachytron*, is probably correlated with their habits of hiding under rocks in fast mountain-streams, where the act of inspiration is perhaps difficult and intermittent.

2. Foliate Type.

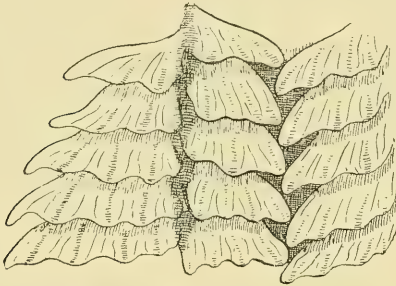
We now pass on to a very interesting type of gill, found only, so far as is known, in the two large and widely distributed genera *Æschna* and *Anax*, both belonging to the tribe *Æschnini* of the subfamily *Æschninæ*. Of these two genera, *Æschna* alone exhibits the normal or typical foliate gill-form. In *Anax* there is an additional complication in the form of an abundant development of small papillæ. We must, therefore, subdivide the foliate type into two sub-types—the *normal foliate* type of *Æschna*, and the *papillo-foliate* type of *Anax*.

2 A. Normal Foliate Sub-type. (Text-figs. 6-7 ; Plate 19. figs. 5-6 ; Plate 21. fig. 15 ; Plate 22. figs. 23, 26.)

This sub-type has been studied by me in *Æschna brevistyla*, and appears to agree very closely with the form of gill found in the Palæarctic members of the same genus. In it the gills of each hemibranch form a series of leaves with narrowed stalks and broadly expanded distal ends. The secondary efferent trachea forms the axis of each stalk, while the capillaries are confined to the expanded leaf. On entering the base of the leaf the

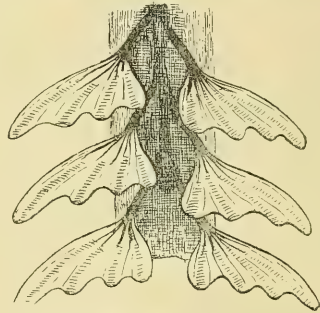
secondary efferent trachea gives off branches, which branch again and again until the whole leaf is supplied with an immense number of capillaries. The free edge of each leaf is much folded in and out, giving it the appearance seen in a crinkled rhubarb or cabbage leaf. Fat-globules and dense purplish-brown pigment are plentifully distributed, not only in the basal swellings of the rectal epithelium, but also in the leaves themselves. The thickness and complexity of the formation, together with the dense pigmentation, make it impossible to do justice to its appearance in a photograph.

The leaves or *foliæ* arising in two longitudinal rows from one holobranch tend to diverge distally. But the *foliæ* from right and left halves of two consecutive holobranchs do not come into very close contact, because each *folia* assumes a direction nearly transverse to the long axis of the gill-basket. Thus all the *foliæ* come to project into the cavity at approximately equal intervals apart, the distal end or tip of each lying so as just to interpose



TEXT-FIG. 6.—*Aeschna brevistyla*, Ramb.

Portions of three hemibranchs from the anterior portion of the everted gill-basket of a larva at about the 10th instar. *Normal Foliate Sub-type*. Semi-diagrammatic, drawn from the freshly-opened gill-basket. ($\times 50$.)



TEXT-FIG. 7.—*Aeschna brevistyla*, Ramb.

Portions of two hemibranchs from the posterior narrow portion of the gill-basket of the same larva. *Normal Foliate Sub-type*. Semi-diagrammatic, drawn from the freshly-opened gill-basket. ($\times 50$.)

itself into the space left between two consecutive *foliæ* of the next hemibranch (text-fig. 6). Hence, on everting a gill-basket of *Aeschna* by a longitudinal cut, one notices at first twelve rows of leaves arranged in six sets in which the distal ends of the leaves face one another, while the tracheal axes appear to diverge from the region of a longitudinal axis which is the true axis of symmetry of each holobranch. The two hemibranchs really belonging to one holobranch have their *foliæ* arranged so as to diverge away from one another distally.

Arrangement of the Tracheæ.—If one of the *foliæ* be dissected out, and its free border smoothed out by means of a camel's-hair brush, it will be seen

that the arrangement of the tracheæ is very similar to that already seen in *Austroeschna*. There is, however, a more complicated branching of the tracheæ, and the finer branches run very close up to the border of the leaf, giving off numerous fine capillaries which arch along the free border of the leaf, and then turn over downwards to join other branches. These latter unite up, finally, to enter the main trachea of the gill at a different level. Thus the whole folia, but especially its free distal border, is richly supplied with capillaries.

Differentiation of the Posterior Portion of the Gill-basket.—In the gill-basket of *Æschna* there is a very large and broad anterior portion followed by a much smaller and narrower posterior portion. On everting the basket by a longitudinal cut, it will be seen at once that there is a difference in the arrangement of the foliæ in the anterior and posterior portions. In the anterior portion the foliæ are closely crowded together, the spaces between succeeding foliæ in a hemibranch being very short. In the posterior portion, however, the number of foliæ is very small; they are exceedingly well developed, and seem to lie more freely in the rectal cavity. Also they are separated from one another by much wider intervals. Text-fig. 6 shows the arrangement of the foliæ in the anterior part, while text-fig. 7 shows some foliæ from the posterior part.

Presence of Aborted Main Longitudinal Folds.—In order to show these clearly, I fixed and cleared the whole abdomen of a well-grown larva of *Æschna brevistyla*. While in cedar-oil, this was cut into thick transverse sections (2 mm.) by means of a sharp razor. On examining these sections under a low power, the six main longitudinal folds developed in the *Simplex System* of the young larva (see p. 181) could be clearly made out, separating the double rows of hemibranchs of the *Duplex System* of the more mature larva. They are devoid of dark pigmentation, and carry no tracheæ. They may be followed right back to the posterior end of the gill-basket, where they pass into the six corresponding "rectal glands." The small posterior terminations of the gill-hemibranchs may be actually seen in the same section as the "rectal glands," at the posterior end of the gill-basket, which in this genus passes, without any sphincterial separation, into the anal portion of the rectum (text-fig. 8).

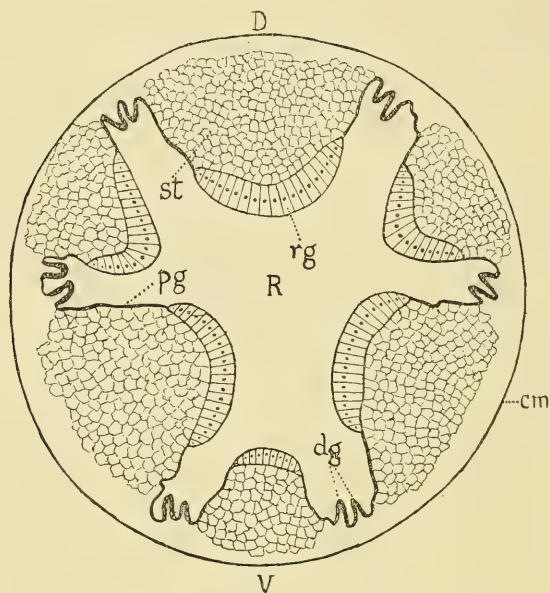
The study of this genus, then, makes it quite certain that the main longitudinal gill-folds of the *Simplex System* are actually homologous with the so-called "rectal glands," with which they agree both in number and position.

Number of Capillaries in the Gill-basket.

In *Æschna brevistyla* there are 16 foliæ in a hemibranch (rarely 17 or 18). In each folia there are 8 or more branches of the main tracheal stalk, and each branch may be credited with a minimum of 50 capillary loops. Hence

we get a total of $12 \times 16 \times 8 \times 50$ or 76,800 complete capillary loops in the gill-basket! This enormous number, together with the great increase in pigmentation, represents a very distinct evolutionary advance over the Implicate Type.

Origin of the Foliate Type.—This type is easily derivable from a simple form of the Implicate Type. If each gill in the latter type were to become constricted off below its middle, it would quickly take the form of a separate leaf, supported on a stalk in which the efferent trachea ran. The “frills”



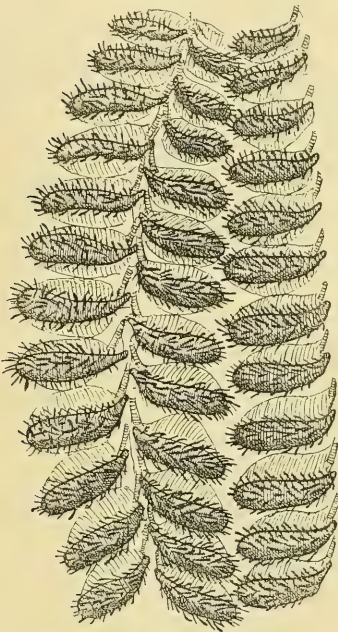
TEXT-FIG. 8.—*Aeschna brevistyla*, Ramb.

Transverse section through extreme posterior end of gill-basket, showing the reduced and highly-pigmented gills lying between the so-called “rectal glands.” Section cut from a larva which had just completed its ecdysis into last larval instar. Semi-diagrammatic. ($\times 72$) *cm*, circular muscle; *D*, mid-dorsal position; *dg*, duplex gill-system; *pg*, pigmented rectal epithelium; *R*, rectum; *rg*, raised epithelium of “rectal gland”; *st*, supporting-tissue; *V*, mid-ventral position.

on the edge or “lip” of the groove would then correspond to the “crinkles” on the leaf. Finally, if each separated groove became elongated transversely to the longitudinal axis of the gill-basket, and came to lie more transversely to that axis, we should then obtain a strictly foliate type of gill-structure, only differing by the absence of fat-globules and dark pigmentation from the foliate gill of *Aeschna*.

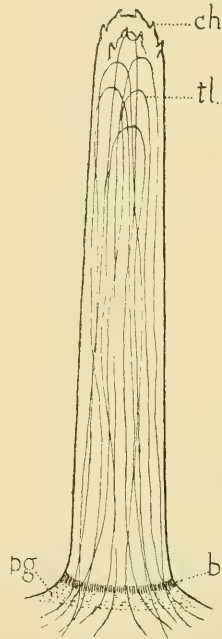
2 B. **Papillo-Foliate Sub-type.** (Text-figs. 9-10; Plate 19. figs. 7-8; Plate 21. figs. 16, 19.)

The very remarkable form of foliate gill-type found in *Anax* has been studied by Dufour, Oustalet, and others. All of these authors up to Poletaiëw believed that this type of gill belonged to the genus *Æschna*, but none of them attempted to breed out the larva which they were studying. Poletaiëw, who studied undoubted larvæ of *Æschna*, failed to find the



TEXT-FIG. 9.—*Anax papuensis*,
Burm.

Three complete hemibranchs from the everted gill-basket of a full-grown larva. *Papillo-foliate Sub-type*. Semi-diagrammatic, drawn from a whole mount. ($\times 40$.)



TEXT-FIG. 10.—*Anax papuensis*,
Burm.

A single papilla from the same larva. ($\times 360$.) *b*, base; *ch*, chitinous hooks; *pg*, pigmented epithelium of the basal hump; *tl*, loops of tracheal capillaries.

papillæ mentioned by these earlier authors. She therefore questioned the accuracy of their descriptions, but failed to discern the true cause of the discrepancy. It remained, then, for Ris to show that the truly *papillo-foliate* gill belonged to the genus *Anax*. My own studies of this type have been carried out on the larva of *Anax papuensis*.

The structure of the separate leaves in *Anax* is very easily understood, in spite of their complexity. Each leaf, instead of being of the crinkly cabbage-

leaf form seen in *Æschna*, forms a transversely-elongated oval hump, borne upon a slender stalk whose axis is a secondary efferent trachea. It is this character of the *narrow stalk* which is typical of the foliate type, and distinguishes it from all others. In *Anax*, these leaf-stalks are not quite so long as in *Æschna*, and consequently the leaves do not project so far into the rectum. There are twelve leaves or humps in each row in *Anax papuensis*. Rarely, thirteen or fourteen occur. The positions of the leaves or humps in *Anax* correspond exactly to those of *Æschna*, except that they are elongated in a direction *at right angles* to the longitudinal axis (those of *Æschna* are elongated at a somewhat less angle). The relationships of the rows of leaves in consecutive hemibranchs are the same as those already explained in *Æschna*. Fat-globules and dark pigmentation are present as in *Æschna*, the pigmentation being even deeper than in *Æschna*, and of a purplish-black colour.

Structure of the Papillæ.—The most striking feature in the gills of *Anax* is the very remarkable formation of small papillæ all over the free surface of each leaf or "hump," which is called on that account by Ris the "basal hump" (die basalen Höcker)—a very appropriate term, if we remember that the hump is "basal" to the papillæ, but "distal" to the efferent trachea forming the axis of the stalk. Oustalet studied these papillæ very carefully, and gives an accurate description and figure of them. They arise in large numbers as small finger-like eversion of the wall of the whole free surface of the hump. They are not homologous with the papillæ already described in *Hemigomphus*, but have been, like these latter, called forth quite independently, in the process of evolution, by the same necessity for obtaining a better extraction of oxygen from the water in the rectum.

Each papilla is of cylindrical shape, with a rounded tip. In proportion, they are shorter and thicker than the papillæ of *Hemigomphus*. Within the papilla *there is no axial trachea*, but only a small number of fine capillary loops, which have been, as it were, drawn or sucked up into the papillar eversion, out of their original course along the surface of the hump, so as to complete their loopings within the papilla. Oustalet estimated that each hump carries a hundred of these papillæ. The number of capillary loops in each separate papilla of *Anax papuensis* varies from five to eight, the average being six (text-fig. 10).

In the cuticle of these papillæ there are no transverse chitinous rods such as are to be seen in those of *Hemigomphus*. At their rounded ends, however, there are a number of little curved chitinous hooks, which probably serve the same purpose as the rods.

Owing to the comparative thickness of the basal humps and the density of their pigmentation, they are even more unsatisfactory for photography than are the foliæ of *Æschna*. Plate 19. fig. 8 shows a profile view of one hemibranch of a half-grown larva, while fig. 7 of the same Plate shows the front

view of parts of two hemibranchs from a somewhat younger larva (7th instar). The drawing in text-fig. 9 is taken from a photograph of the everted gill-basket of a full-grown larva, part of which is reproduced in Plate 21. fig. 19.

Number of Capillary Loops in the Gill-basket.

For the larva studied by him (probably *Anax junius*) Oustalet calculated the number of capillaries at 120,000, allowing only 5 loops to each papilla, 100 papillæ to each hump, and 20 humps in a hemibranch. In *Anax papuensis* there are only 12 humps in a hemibranch, but the average number of loops in each papilla appears to be six rather than five. Hence the approximate total for *A. papuensis* is $6 \times 100 \times 12 \times 12$, or 86,400 complete loops. Oustalet's larva was larger than the one studied by me—hence his total may be well within the mark for that species. *Anax papuensis* is one of the smallest species of the genus, so that we cannot be wrong in stating the average number of loops in larvæ of this genus at over 100,000. Probably an investigation of the larva of one of the largest species, such as *A. gibbosulus*, would yield a very much higher total.

Origin of the Papillo-foliate Sub-type.

It is difficult to indicate precisely the reason for the cænogenetic development of the papillæ on a form of gill already so highly specialized as the *Foliate Type*. In studying the larvæ of *Anax papuensis* and *Æschna brevistyla*, it seemed to me that the reason might be sought for primarily in the difference of habitat. The *Æschna* larva lives in slowly-running water, while that of *Anax* inhabits stagnant pools. Hence it seemed probable that the poorer aëration of the water breathed by the *Anax* larva might have called forth, in the process of evolution, a correspondingly more efficacious type of gill. An objection to this view is that the larvæ of those Palæarctic species of *Æschna* which inhabit stagnant water have not developed papillæ. But it seems probable that the larvæ of the genus *Æschna* all originally inhabited running water. Hence, if the habit of breeding in still water, in the case of these Palæarctic species, is of very recent requirement compared with the same habit in *Anax* larvæ, my supposition may well be correct.

Dr. Ris has suggested to me (*in litteris*) that the papillæ are correlated with *quickness* of development. The larvæ of all species of *Anax* reach maturity in one year, while those of *Æschna* nearly always take two or three years. Dr. Ris thinks that the rapid growth of the *Anax* larvæ may be principally due to the increased oxygenating power of the respiratory system, due to the presence of the papillæ. This explanation seems to me to be a good one. But it cannot account entirely for the difference in speed of growth. For, as will be shown later (p. 179), the newly-hatched larvæ of

both *Anax* and *Æschna* have gills of exactly similar structure; and, in *Anax*, the papillæ do not begin to develop until the sixth instar. Yet the young larva of *Anax* grows very much more rapidly than the young larva of *Æschna*.

It seems, therefore, that other factors must also play a part in the difference between the two larvæ. I think that one of these two factors is the earlier appearance of the imagines of *Anax*, and the consequent hatching of the larva at a time when the organic life of the ponds is at a maximum. The imagines of the various species of *Æschna* almost all appear late in the summer. Hence the larvæ must hatch out in the autumn, or possibly not until the following spring. Another factor which must play some part is the more sluggish character of the *Æschna* larvæ. I have always found the larvæ of *Anax papuensis*, in my aquaria, to be far more greedy and rapacious than any other Odonate larvæ known to me. The larva of *Æschna brevistyla*, on the other hand, though rapacious enough compared with other Odonate larvæ, cannot be compared with that of *Anax*, either in its alertness in watching for prey or in its capacity for taking food.

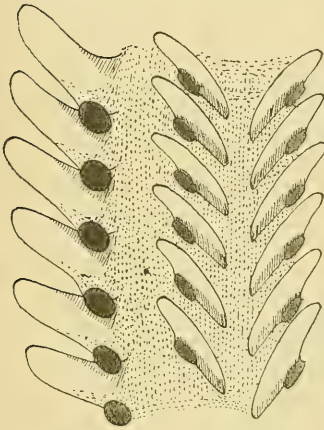
It would seem then that all four causes mentioned above may play a part in differentiating these larvæ one from the other.

3. Lamellate Type. (Text-figs. 11-14; Plate 20. figs. 9-12; Plate 21. figs. 13, 14, 20, 21; Plate 22. figs. 24, 27.)

This very distinct and beautiful type of gill-structure is found throughout the whole family of the Libellulidæ. I have studied it in the genera *Synthemis*, *Metathemis*, *Austrocordulia*, *Hemicordulia*, *Cordulephya*, *Orthetrum*, and *Diplacodes*. Sadones's investigations were carried out entirely on the single species *Libellula depressa*, while Ris has studied the gills of European species of the genera *Cordulia*, *Orthetrum*, *Libellula*, and *Sympetrum*. Though, of course, many minor variations in structure are bound to occur throughout so large a mass of forms, yet there are no outstanding differences which seem to me to warrant the erection of sub-types. I propose, therefore, first of all to deal with the general characteristics common to all Lamellate Types of gill, and then to describe the more noticeable differences that appear under the various generic headings.

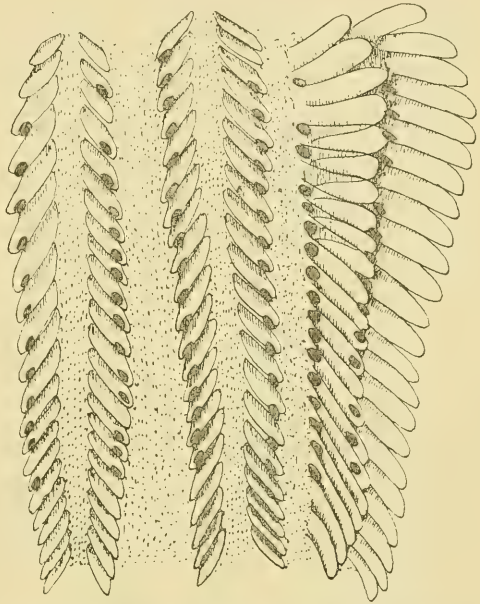
When a lamellate gill-basket is everted by a longitudinal cut, it becomes thrown into a very strongly convex form (the internal portion forming the convexity) so as to resemble a Chinese paper lantern partly opened. On examining this with a low power, six double rows of very regularly arranged flat leaf-like gills or lamellæ are seen projecting from its surface. This very neat and orderly arrangement is in very strong contrast to that exhibited by any other type of gill-basket, and points to the lamellate type as the most perfect form of gill-basket yet evolved.

The general arrangement of the gills is easily understood from text-figs. 11, 12. Each holobranch consists of two exactly similar hemibranchs, symmetrically arranged about a middle line or axis running midway between them. Each hemibranch consists of a single row of gill-lamellæ, ranging in number from twelve to nearly thirty, according to the genus selected. The bases of insertion of these lamellæ are arranged slantwise to the long axis of each holobranch, with their anterior ends close to that axis and their



TEXT-FIG. 11.—*Synthemis macrostigma*, Selys.

Portions of three hemibranchs from the everted gill-basket of a full-grown larva. *Lamellate Type*. The middle and left-hand hemibranchs belong to one holobranch. The right-hand hemibranch is seen in profile from its outer side. Basal pads shown in black. Semi-diagrammatic, drawn from a whole mount. ($\times 30$.)



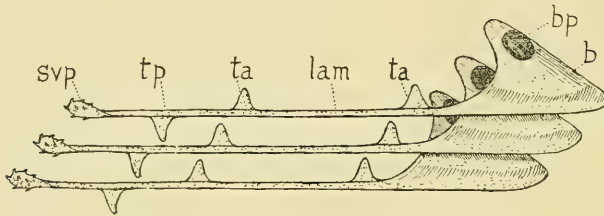
TEXT-FIG. 12.—*Diplacodes hematodes*, Burm.

One-half of the complete gill-basket, everted, from a full-grown larva. *Lamellate Type*. Pigmentation omitted. Basal pads shown in black, mostly seen by transparency through the overlying anterior lamella. Right-hand holobranchs in profile. Semi-diagrammatic, drawn from a whole mount. ($\times 30$.)

posterior ends removed from it. Hence the gills in each holobranch appear to slant away posteriad from the middle line in symmetrical pairs, one on either side of it. It is quite clear, from a comparison of this figure with that of the Undulate Type in the Simplex System, that these gill-lamellæ represent highly-differentiated cross-folds of an originally Simplex System—for they agree exactly with them both in position and direction. The base-lines of the gills of one hemibranch are, as a matter of fact, intermediate in level

between those of the opposite hemibranch, just as one set of cross-folds is intermediate in position to the other.

The base of each lamella is very broad. From it the lamella itself rises up to project into the rectal cavity in a slantwise direction, with the distal end lying towards the posterior end of the gill-basket. The angle between the rectal wall and the gill-lamella is not constant, but varies with the act of respiration. Also the broad basal part of the lamella is not in the plane of the "blade" or main portion, but curves away from it so as to meet the rectal wall, along its base-line, in a gentle incline (text-fig. 13). Thus, if the lamella be viewed edge-on, the basal portion can be seen rising up above the line of the blade, with the prominent basal pad (*bp*) lying upon it. When the rectum is expanded, the gills stand up in serried ranks, nearly normal to the rectal wall. When the rectum is contracted, the lamellæ fall down so as to overlap one another, all pointing slantwise towards the posterior end of the basket.



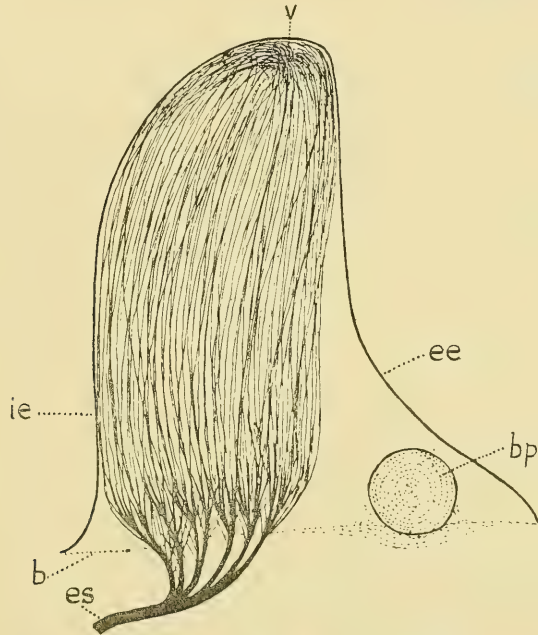
TEXT-FIG. 13.—*Austrocordulia refracta*, Till.

Three lamellæ viewed edge-on to show arrangement of tubercles. Semi-diagrammatic from a camera-lucida drawing. ($\times 90$.) *b*, base of insertion of lamella; *bp*, basal pad; *lam*, blade of lamella; *svp*, supravortical papilla; *ta*, tubercles on anterior face of lamella; *tp*, tubercle on posterior face.

The lamellæ do not, however, lie freely upon one another. They are separated, each from each, by three small tubercles (text-fig. 13) first discovered and described by Sadones in *Libellula*. Apart from these tubercles, the cuticle of the lamella is in most cases perfectly smooth. The tubercles are situated as follows:—One (*tp*) lies near the tip of the lamella on its posterior or lower face; a second (*ta*) lies somewhat distally from the middle on its anterior or upper face; and a third (*ta*) lies close to the base, also on the anterior or upper face. By means of this arrangement, each lamella is separated from the one below it by a *tripod* of three tubercles, of which the outermost belongs to the upper lamella, the two others to the lower. Thus, in all positions of the lamellæ, a constant flow of water can circulate between and around each separate lamella. The advantages of this arrangement for the extraction of oxygen by the gills are so obvious as to need no special comment. In *Austrocordulia refracta* (text-fig. 13) the

tubercles are more prominent and sharply pointed than in most Libellulid genera, and are very clearly seen in profile under a low power.

Basal Pads.—One of the most striking differences between the Lamellate Type of gill and all other forms is the presence of large basal pads belonging to each lamella. These are easily to be seen under a very low power (in *Synthemis* with the naked eye), because of their deep semi-transparent brownish or orange-brown colour. They were first discovered and described by Sadones. If a complete everted gill-basket be examined, it will be seen



TEXT-FIG. 14.—*Hemicordulia tau*, Selys.

A single lamella from a full-grown larva, viewed from the anterior or upper surface. Camera-lucida drawing. ($\times 80$.) *b*, base of insertion of lamella; *bp*, basal pad; *ee*, external edge of lamella; *es*, secondary efferent trachea; *ie*, internal edge of lamella; *v*, vortex of capillaries.

that one of these basal pads is attached to each of the gill-lamellæ, except the first one or two and the last four or five in each hemibranch. (Usually also one can find one or two lamellæ near the middle, here and there, which lack them also.)

The basal pads are a series of rounded disc-like swellings formed in the rectal epithelium at the base of each lamella. They lie towards the outer ends of the lamellæ on the anterior or upper border.

The complete study of these interesting organs, which, although not visible as separate entities in any except the lamellate type of gill, occur in

all forms of gill-basket, is the subject of a special section of this paper (pp. 170-177).

Shape of the Lamellæ.—Text-fig. 14 gives us a very good idea of the general shape of a typical lamella. The base is very broad, and the lamella rises up very unsymmetrically from it. From the outer or distal end, towards which the basal pad lies, the edge of the lamella rises up at a gentle slant, which gradually increases towards the tip. But from the inner end the lamella rises up much more sharply, forming a more regular oval curve. The tip of the lamella may be evenly rounded, or somewhat “nodding” towards the outer side.

Tracheal Supply.—The distribution of primary and secondary efferent tracheæ to the gills is typically that described already for the *Duplex System*, and need not be repeated here (see Plate 22. fig. 27). The tracheal supply of the lamellæ is, however, of great interest. Each lamella receives, beneath its base, one large secondary efferent trachea, which breaks up at once into a number of branches *arising close together*, nearly, but not quite, all at the same level. From these branches there arise whole bundles or pencils of tracheal capillaries, all again very nearly at the same level, close to and just within the base of the lamella. Thus practically the whole of the lamellar area contains capillaries only. The advantages of this arrangement also, for the purpose of the extraction of oxygen, is so obvious as to need no comment.

The capillaries run all very nearly parallel along the lamella until they reach its distal end, where they all loop over inwards to return more along the middle of the lamella, finally entering other bundles which join up to form branches of the secondary efferent below the gill-base. This looping of nearly all the capillaries inwards gives rise, in most cases, to a very characteristic appearance of the capillaries just under the rounded distal end of the lamella, an appearance which I propose to call the *lamellar vortex*. It is most clearly seen in some genera of *Corduliinæ* (text-figs. 14, 15). The in-turning of so many capillaries near the middle line of the gill gives a very distinct appearance of a *vortex* of capillaries at this point. In those genera of *Libellulinæ* in which the tip of the lamella is very regular and rather flat, this vortex is not at all noticeable (Plate 21. fig. 13).

I now propose to take the various genera in phylogenetic order, and indicate the principal peculiarities in the gill-basket of each.

(1) *Synthemis* and *Metathemis*.—The form of the gill-basket is almost exactly the same in the larvæ of *S. eustalacta*, *S. macrostigma*, and *M. guttata*. This form may therefore be considered to be typical of the archaic tribe *Synthemini*. The gill-basket is very small for the size of the larva, and is found on eversion to be of a pure shining white colour without any trace of pigmentation whatever. In each hemibranch there are only *twelve* lamellæ, as against a number varying from twenty to thirty in all other genera of *Libellulidæ*.

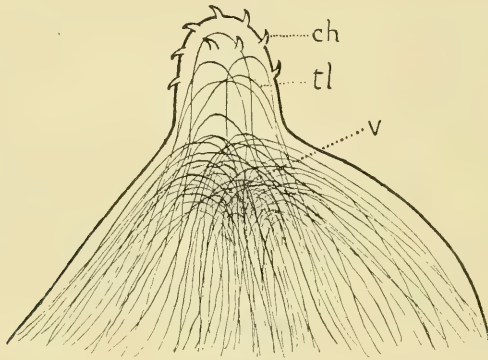
Another striking peculiarity of this gill-basket is the enormous size of the basal pads (text-fig. 11). These appear like rows of large brown buttons along the sides of the lamellæ, and are easily seen with the naked eye. These organs certainly reach their greatest development in this tribe. Their large size indicates probably, however, an earlier stage in the *localization* of these organs as appurtenances of the separate lamellæ. Originally, in the Simplex System, they spread along the whole anterior border of the cross-folds, besides supporting the main folds. When these latter deteriorated, and the cross-folds began to develop as lamellæ, localization of the basal pad began in the shape of a condensation to a rounded pad in a fixed position, with corresponding deepening of pigmentation. Hence the enormous pads of the *Synthemini* may be rightly regarded as an intermediate stage between the non-localized pads of the Simplex System and the extremely reduced separate localized pads of the higher Lamellate Types.

The shape of the lamellæ in the *Synthemini* is fairly typical of the sub-family *Corduliinæ* as a whole, as well as of the lower *Libellulinæ*. Each lamella is distinctly "hump-backed" or "nodding," the inner edge being much more convex than the outer, so that the lamellæ "nod" away from the axis of the holobranch, slantwise towards the posterior end of the rectum. Owing to the narrowness of the gill-basket, the lamellæ of the *Synthemini* are not so elongated as those of other genera. This is particularly noticeable in *Metathemis guttata*, where the breadth of the lamella near its base is nearly as great as the length from base to tip (Plate 20. fig. 9). A distinct tracheal vertex is always present. The capillaries, though very numerous, fall behind those of other genera in fineness.

(2) *Austrocordulia*.—The lamellæ of the gill-basket in the larva of this genus, the only one known for the tribe *Idocorduliini*, is the most remarkable in the whole range of the Lamellate Type. There are a very large number of lamellæ (26 to 30) in each hemibranch, and they are closely packed together. The tubercles separating the lamellæ are large, and easily seen under a low power. The basal pads are fairly large, showing a very dark brown circumference with a pale orange-brown centre. The lamellæ themselves are of typical Corduline form, strongly nodding, considerably longer than wide, and carry a very large number of capillaries of moderate fineness. But the most extraordinary thing about them is that each lamella is furnished, at its nodding tip, *with a short and well-developed papilla*. This papilla I propose to call the *supravortical papilla*, since it lies directly over the lamellar vortex (text-fig. 15). The papilla is a simple eversion of the wall of the lamella at its tip, into which a very few capillary loops have been drawn or sucked. Its structure is essentially similar to that of the papillæ in *Anax*, from which it differs only in being much shorter and wider. Its cuticle is armed with nine or ten strongly-hooked chitinous teeth, all bent towards the outer edge of the lamella. Text-fig. 15 shows this papilla highly magnified.

This papilla also seems to me to be homologous in structure with the tubercles already mentioned. The papillæ in *Anax* arise as small tubercles into which, later on, capillaries become sucked or drawn in. In the case of the tubercles, the swelling up the wall only affects the local epithelium to such an extent as to cause a swelling or thickening of it in the region of the tubercle. By further eversion, the epithelium, and later on the capillaries running in it, could be so drawn out as to bound a hollow cylindrical process—that is to say, a typical respiratory papilla.

The lamellæ in *Austrocordulia* are delicately tinted with a pale mauve or purplish pigment.



TEXT-FIG. 15.—*Austrocordulia refracta*, Till.

Tip of lamella, with supravortical papilla. From a photomicrograph. ($\times 420$.) *ch*, chitinous hooks on papilla; *tl*, loops of capillaries within the papilla; *v*, vortex of capillaries.

(3) *Hemicordulia* (text-fig. 14; Plate 20. fig. 12).—The form of the lamellæ in this genus, representing the tribe *Eucorduliini*, is very typical of that tribe. Each lamella is about twice as long as its breadth across the middle; the actual base-line, however, being much wider, owing to a long slender extension of the distal edge of the lamella. The tip is almost right-angled, the distal or outer edge being nearly straight in this region, while the inner edge is broadly convex. The lamellar vortex is very close to the tip, and only moderately well formed. The number of lamellæ in a hemibranch is usually 24, sometimes 25 or 26. The basal pads are small rounded discs, of a transparent orange-colour. The whole of the gill-apparatus is suffused with the most beautiful delicate purplish-mauve pigment. The capillaries are numerous and of considerable fineness.

(4) *Cordulephya* (Plate 22. figs. 24, 27).—The gill-basket of this interesting genus very closely resembles that of *Hemicordulia*. The lamellæ, however, are slightly longer and narrower, and more regularly rounded at the tips. They resemble the lamellæ of the more typical *Libellulinae* more

than those of any other Corduline genus known to me. There are 22–24 lamellæ in a hemibranch. Delicate purplish-mauve pigment is present as in *Hemicordulia*. There can be no doubt that the form of the gill-basket in this genus is further definite evidence in favour of its being a highly specialized offshoot of the *Eucorduliini*.

(5) *Orthetrum* (Plate 21. figs. 13, 14).—In this genus we see the lamellæ taking on a somewhat more symmetrical shape than is to be noticed in the *Corduliinæ*. This tendency towards symmetry in the form of the upper part of the lamella seems, indeed, to be typical of the *Libellulinæ*. The lamellar vortex is absent, the tips are wide, well rounded, and rather flat, so that the bent or “nodding” effect is almost wholly lost. The lamellæ lie very close together, so that, when a portion of a hemibranch is spread out on a slide, each lamella overlaps not only the one next to it posteriorly, but also a portion of a second one as well. The general effect is one of greatly increased regularity as compared with the type of lamella seen in the *Corduliinæ*.

In *Orthetrum caledonicum* there are 24–26 lamellæ in a hemibranch. The whole gill-basket is of a pure shining white colour, without any trace of pigmentation.

(5) *Diplacodes* (text-fig. 12 ; Plate 21. fig. 21).—This genus shows the most advanced development of the Libelluline type of lamella known to me. The general shape of the lamellæ, which number from 26 to 30 in a hemibranch, is the same as in *Orthetrum* ; but, if anything, the symmetry of the tip is even more marked. A further advance on *Orthetrum* is that the whole gill-basket is so closely pigmented as to appear almost jet-black when cut open. When examined under a low power this pigment is seen to be of a deep purple colour, and is much denser at the bases of the lamellæ than towards their tips. In both *Diplacodes* and *Orthetrum* the capillaries are excessively fine and numerous.

Reviewing the above variations of structure in the Lamellate Type of gill-basket, we see that there is a progressive development from the lower to the higher forms, from which *Austrocordulia* stands out as a separate side-branch, in which an attempt is made to reproduce the papillæ so successfully developed in *Anax*. In some lamellæ taken from a larva of *Hemicordulia tau*, I have noticed the beginnings of a similar attempt at papilla-formation. It seems, therefore, unnecessary to name any sub-types within the Lamellate Type—especially as, when the number of known forms is increased, we may expect to find further intermediate links in the evolutionary chain.

It remains true, nevertheless, that the gill-basket of the *Synthemini* is at once distinguished from all the rest by the size of its basal pads and the small number of lamellæ in a hemibranch, while, amongst the rest, the gill-baskets of the *Libellulinæ* exhibit a general difference from those of the *Corduliinæ* by the greater symmetry of form and the closeness of arrangement of their lamellæ. Hence, if at any time it is desired to subdivide the

Lamellate Type into sub-types, we might propose the term *Archilamellate* for the sub-type exhibited by the *Synthemini*, as contrasted with the *Neolamellate* sub-type found in the other genera. Within the *Neolamellate* sub-type we might then recognize two forms of lamellæ, viz., the *Corduline* form, the more asymmetrical, and the *Libelluline* form, the more symmetrical.

Number of Capillaries in the Gill-basket.—It will be sufficient to indicate the approximate number in the five genera above studied. In *Synthemis* the capillaries are only of moderate fineness, and may be reckoned at only 100 to each lamella. Hence we get a total of $12 \times 12 \times 100$, or only 14,400 capillary loops in this gill-basket. In *Austrocordulia*, there are probably 150 or more capillaries in each lamella. Hence the total for this genus will be $28 \times 12 \times 150$, or 50,400, allowing 28 as the average number of lamellæ in a hemibranch. In *Hemicordulia* the greater fineness of the capillaries may be represented by reckoning 200 in each lamella. Thus the total for the genus is $25 \times 12 \times 200$, or 60,000. In *Cordulephya* the narrowness of the lamellæ allows us only to reckon 150 capillaries in each, in spite of their fineness. Counting, then, 23 lamellæ to the hemibranch on the average, we have a total of $23 \times 12 \times 150$, or 41,400. In *Orthetrum*, again, we can reckon on at least 200 capillaries in each lamella, with an average of 25 lamellæ to the hemibranch. This gives us $25 \times 12 \times 200$, or 60,000, the same as in *Hemicordulia*. The greatest total is given by *Diplacodes* with an average of 28 lamellæ to the hemibranch, yielding a total of $28 \times 12 \times 200$, or 67,200 capillary loops. This number, though it falls short of that calculated for the Foliate Type, belongs, it must be remembered, to a much smaller larva, besides which, the arrangement of the gills in the Lamellate Type is such as to give unrivalled advantage in the extraction of oxygen. We need not be surprised therefore at the fact that the larvæ of *Diplacodes*, *Cordulephya*, and other Libellulid genera develop very rapidly, and pass into the imaginal state well within a year from the time of hatching. What we may well wonder at, however, is the fact that the larva of *Austrocordulia*, in spite of its highly developed gill-basket, takes four or five years to mature. This points, indeed, to some special disability not connected with the oxygen-supply. That disability is, I think, the sluggish habit of the larva, which hides away under rocks or débris, and feeds but seldom.

Comparison of the Efficiency of the Gill-basket in the various Types.

The numbers given as the totals for the capillary loops are in all cases only approximate, and are intended to give an idea of the comparative numerical abundance of capillaries rather than their actual numbers. If we look upon each capillary as a unit for the extraction of oxygen, they enable us to compare the relative values of the different types of gill-basket as oxygen-extractors. It must not be forgotten, however, that the value of the unit also depends upon the length of it exposed to the direct action

of respiration. In this respect the Undulate Type is distinctly at the greatest disadvantage, the Lamellate Type, on the other hand, easily the most advantageous. Forms in which papillæ are developed clearly have an advantage over similar forms without papillæ; but it is doubtful whether a single folia of *Anax*, with all its papillæ, is of any greater value in extracting oxygen than is a single gill of the Lamellate Type.

The following table gives a comparative summary of the number of capillary loops calculated for the different genera examined. The totals are only approximate, but the degree of error in each is probably very much of the same order:—

Species.	System.	Type.	Approximate total.
<i>Austrogomphus ochraceus</i>	Simplex.	Undulate.	10,800 *
<i>Petalura gigantea</i>	"	"	20,000
<i>Hemigomphus heteroclitus</i>	"	Papillate.	18,000
<i>Austroæschna multipunctata</i> . .	Duplex.	Implicate.	28,800
<i>Dendroæschna conspersa</i>	"	"	46,080
<i>Æschna brevistyla</i>	"	Foliate.	76,800
<i>Anax papuensis</i>	"	"	86,400 †
<i>Synthemis macrostigma</i>	"	Lamellate.	14,400
<i>Austrocordulia refracta</i>	"	"	50,400
<i>Hemicordulia tau</i>	"	"	60,000
<i>Cordulephya pygmæa</i>	"	"	41,400
<i>Orthetrum caledonicum</i>	"	"	60,000
<i>Diplacodes hæmatodes</i>	"	"	67,200

Origin of the Lamellate Type.—It is a matter of great regret to me that, during the year in which this research has been carried out, I have been unable to obtain any Libellulid ova for hatching out the young larvæ. The smallest larvæ that I have been able to obtain were of the genus *Diplacodes*, and measured from 2 to 3 mm. in total length of body. I consider these larvæ to belong to the third or fourth instar. Several of these were sectioned. The results showed, not only that the *Lamellate Type* of gill was already fully established, but that basal pads were already fairly well formed. In no case was I able to discover any sign of the main longitudinal gill-folds of the *Simplex System*, which are the principal breathing-organs in the young larvæ of *Æschna* and *Anax* (p. 143). It is, therefore, clear that the *Lamellate Type*, though necessarily classed within the *Duplex System* because of its structure, has no close phyletic connection with those other types of the

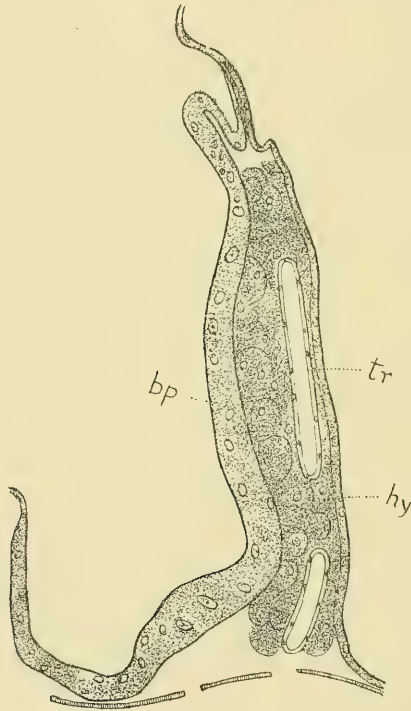
* Minimum.

† Maximum.

Duplex System which we find in the subfamily *Æschninae*. The point cannot be definitely settled, of course, without a careful study of the gill-basket of some newly-hatched Libellulid larva. This I hope to carry out shortly. Meanwhile, we must be content to regard the *Lamellate Type* as arising from a very simple and early form of the *Simplex System* by the complete suppression of the main folds, and the development of the cross-folds into lamellæ.

THE BASAL PADS. (Text-fig. 16 ; Plate 22. figs. 25-27.)

We owe to Sadones a very excellent and careful study of these interesting organs in *Libellula depressa*. In this species—and, in fact, in all the Libellulidæ—the formation of the basal pads is very highly specialized. Clearly, then, it would be both unwise and unprofitable to speculate on the origin of such a highly developed structure without at first studying its formation in the less



TEXT-FIG. 16.—*Dendroæschna conspersa*, Till.

Transverse section through base of gill from a full-grown larva. ($\times 440$.)

bp, basal pad ; *hy*, hypobranchial tissue ; *tr*, trachea.

highly specialized form of gill-basket. In attempting to indicate the boundaries of each cell-territory of this peculiar structure, it is probable that Sadones was somewhat misled by his lack of knowledge of the structure

of this organ in other forms besides *Libellula* ; for, as we shall show, the basal pad was first formed *much later than* the establishment of the syncytial nature of the rectal epithelium, and hence must be regarded as *never having possessed separate cell-territories at all*.

Looking through our series of gill-forms, we are at once struck with the fact that it is not in the *Simplex System*, which is phylogenetically the most archaic, that the simplest form of basal pad is found. This is, perhaps, explicable on the supposition that the more isolated positions of the gill-folds in the *Simplex System* render the support of basal pads more necessary than is the case with the *Duplex System*. In any case, it is a fact that well-developed basal pads occur in all forms except the *Implicate Type* of the *Duplex System*. We shall therefore select, first of all, for study the basal pads, if such they may be called, of *Dendroæschna conspersa* (text-fig. 16, *bp*). It is only necessary to recall, in attempting to explain the rudimentary nature of these structures, the fact that in the *Implicate Type* of gill the separate grooved folds lie alternately with their rounded ends supported along a wavy central line, so that there is actually no complete separation of the separate portions of the holobranch into foliæ or lamellæ. Hence the holobranch is more or less self-supporting, and a well-developed basal pad is not wanted.

In *Dendroæschna* the base of the gill-fold is only very slightly enlarged to receive a narrow elongated strip of hypobranchial tissue (*hy*), in which the gill-trachea (*tr*) runs so straight and regularly that it is very often met with from end to end in the same cross-section. Our figure shows it cut in two places. On the inner side of the gill-fold, the ordinary flat syncytial epithelium borders the hypobranchial tissue along its whole length, and passes round along an arc of the rectal circumference for a short distance, to rise again towards the interior on the internal side of the next gill-fold. But, in sections which show the efferent trachea, the *external* epithelium of the base of the gill-fold is slightly swollen into a rudimentary basal pad (*bp*). The protoplasm of this pad shows, so far as I have been able to study it, no trace of any fibrillar structure. It is, in fact, similar to the protoplasm of the epithelial syncytium in its ordinary flat condition, except that it stains slightly darker with hæmatoxylin. Towards the two ends of the pad the nuclei are rather numerous, but not different in size or structure from those met with in other parts of the syncytium. But, in the main portion of the pad, the nuclei are very distinctly enlarged, mostly very distinctly oval in form, and show granular contents, and in many cases a fairly distinct nucleolus. On the whole, these nuclei stain less deeply than those of the syncytium, and their contents are more clearly differentiated.

Passing away from the level of the efferent trachea, the sections show a rapid decrease in the width of the basal pad, which very soon merges into the typical epithelial syncytium of the gill-fold. These pads, therefore,

appear to be in the nature of rudimentary supports developed in conjunction with the main efferent tracheæ and their accompanying hypobranchial tissue. But, uninteresting as the structure of the basal pad in *Dendroæschna* may be, it nevertheless allows us to make certain very obvious deductions. The first is that it is almost certain, with this example before us, that all basal pads arose merely as swellings in an originally uniform epithelial syncytium. The second is that they were probably called forth to act as supports for the bases of the projecting gills, and play no part in the physiological process of the extraction of oxygen from the water in the gill-basket. The third deduction is that the basal pads *never possessed separate cell-territories*, and therefore that it is useless to try, as Sadones has done, to indicate such territories around each nucleus.

I should like here to digress in order to institute a comparison between the basal pads of the gill-basket and the well-known fibrillar columnar epithelium which supports the "fields" bearing the teeth in the gizzard of Odonate larvæ. There also the need is for a support, and the need is supplied by the specialization of the epithelium underlying the chitinous cuticle. In the gizzard, however, the epithelium is formed of separate cells. Hence we find the columnar support evolved from it also formed of separate cells. These cells, however, agree with the syncytium of the basal pad in having their nuclei enlarged, and in showing a distinct fibrillar structure and a turgescient appearance. The function of these enlarged areas, whether in the gizzard or in the gill-basket, is clearly that of a cushion or support for a structure which might otherwise collapse.

To return to the basal pad. Apart from those of the *Implicate Type* in the *Duplex System*, the basal pads of all forms examined by me show a high degree of specialization. Let us take the pad found in *Austrogomphus ochraceus* (Plate 22. fig. 22). At the bases of both main longitudinal folds and cross-folds, lying on the outer side of the gill-wall, one finds these very prominent pads in all sections. They lie not only along the projecting gill-fold itself, but also partly along a small portion of the circumference of the rectum. In many sections the pad may be seen to be continuous between a main fold and an adjacent cross-fold. In the enlarged figure of a basal pad selected from the section diagrammatized in Plate 22. fig. 22 (fig. 25 of the same Plate), representing the pad marked * in the diagram, the pad will be seen to rear itself high up on one side against the wall of the main fold, while another and shorter portion bends upwards against the base of the cross-fold. Between, a portion of the pad lies on the rectal circumference. If this pad be followed through a number of sections, it will be seen that the part supporting the base of the cross-fold increases as the cross-fold comes to be cut more centrally; afterwards it decreases as the section of the cross-fold decreases.

The pad is continuous at both ends with the epithelial syncytium, and

forms a highly specialized portion of it. Its protoplasm is only very slightly chromatophil, clear, very slightly granular, and having embedded in it a series of comparatively enormous nuclei (nu_1), besides a smaller number of much smaller nuclei (nu_2). There is absolutely no indication of separate cell-territories in this mass. On its external side it is covered by a continuation of the fine cuticle which everywhere overlies the rectal epithelium. On its inner side, it is contained by a very delicate basement-membrane separating it from the adjacent mass of hypobranchial tissue.

The most noticeable feature in the structure of this pad is the abundant fibrils which cross it transversely from side to side. Many of these fibrils are seen to be attached to the nuclei, and therefore clearly do not represent cell-limits. Wherever the pad is bent or creased, there may be seen particularly strong fibrils arising, sometimes in groups, to pass out divergently across the pad. Generally, a number of fibrils pass out from each nucleus and tend to diverge as they approach the border of the pad. The spaces between the fibrils are clear for the most part, appearing slightly more granular towards the edges of the pad. The whole appearance of these spaces suggests a state of turgidity, and they are very probably filled with a liquid of some sort, the actual protoplasm of the pad being confined to the nuclei, the fibrils, and the granular substance which lies close to the borders of the pad.

The large nuclei, which I propose to term the *meganuclei of the basal pad* (nu_1), are rather unevenly scattered through the pad. In *Austrogomphus*, one finds the greater number of them lying rather closer to the external than to the internal border of the pad. In that part of the pad which lies on the rectal circumference, they tend perhaps to lie even more unevenly, for one not infrequently sees one, or two close together, lying fairly close to the basement-membrane. Throughout the pad, there seems to be a tendency for two or three meganuclei to approximate together; so that, in any given section, one meets with several cut through very close together, forming as it were a centre of radiation for numerous fibrils, and followed by a space in which no nuclei are visible.

These meganuclei are all of a somewhat elongate-ovoid shape, showing in a cross-section of the pad an elliptical section with its major axis transverse to the pad, and in longitudinal section of the pad a circular or nearly circular section. Hence they are, in actual shape, elongate *prolate spheroids*, with their axes directed transversely across the pad at right angles to its internal and external borders. If we suppose the basal pads to have been formed by the absorption of some liquid into the protoplasm of a portion of original typically flat epithelial syncytium, in such a way that the swelling took place everywhere generally at right angles to the plane of the epithelium, both the fibrils and the nuclei would become extended in the direction in which we here find them. It seems then probable that the meganuclei were

the *original nuclei* of the epithelial syncytium, which have become enlarged in a given direction by the gradual growth of the pad perpendicular to the epithelial plane.

The meganuclei are chromatophil, staining fairly deeply with hæmatoxylin in contrast to the surrounding substance of the pad. Each meganucleus contains a very definite and darkly staining nucleolus, together with numerous scattered granules, also very darkly staining.

Here and there in the sections of the pad, but more especially towards its ends, there are to be seen smaller nuclei (*nu₂*), which I propose to distinguish by the name *micronuclei of the basal pad*. These are nearly always found to lie near the internal border of the pad. They are darkly stained, usually showing a nucleolus and close granular contents. In shape they appear to be flattened or elongated a little in the opposite direction to the axis of the meganuclei; very often they are nearly circular in cross-section. These I also regard as originally nuclei of the epithelial syncytium, which, for some reason or other, have failed to swell out into meganuclei during the development of the pad. The fact that they lie near the ends of the pad partly explains this occurrence. That they also lie close to the internal border of the pad seems to me a strong argument for the development of the pad by imbibition of watery fluid from the rectum; for, if such be the case, those nuclei which lie closest to the external surface would naturally respond first to the access of fluid.

In putting forward the above theory as to the derivation of the basal pad and its nuclei, I may add that, in young larvæ of *Anax* and *Æschna* which I have examined and sectioned from the first to the fourth instars, there are no traces of basal pads. Their development, then,—in these genera, at least,—takes place in later stages. This fact seems to me to make the supposition of their development by imbibition of water from the rectum a very probable one—at any rate, it could not be urged as a solution if we had found the basal pads already developed in the newly-hatched larva.

The basal pads of *Hemigomphus* and *Petalura* are essentially similar in structure to those of *Austrogomphus*. Those of *Petalura* were, however, not so wide in comparison to their length as in the two Gomphine genera. Little weight, however, can be attached to this circumstance, since the larva of *Petalura* which I sectioned had been in alcohol for over four years, and there were very obvious signs of the complete extraction of the watery fluid from the pads, which in some parts had actually collapsed or broken open, showing clear unstained spaces between the fibrils. The complete absence of any substance between the fibrils in the pads of this larva points to the probability of their original contents having been largely of a watery nature, and gives further support to the theory outlined above.

In the three genera under discussion, as well as in the *Æschninae*, I have never seen, on opening the gill-basket, any sign of definite basal pads of a

rounded or elliptical shape and deep orange-brown colour, such as are readily noticeable in the gill-baskets of the Libellulidæ. The pads do not, in fact, show up until the basket has been sectioned and stained. It is clear then that they are widely diffused structures forming a more or less general support to the gill-folds. Judging by their occurrence in a long series of cross-sections, I conclude that they support the main longitudinal folds alternately on either side, sending off side-branches along the *anterior* sides only of the cross-folds. In this connection it is important to notice that, in the Libellulidæ, the localized oval pads occur only on the *anterior* sides of the gill-lamellæ. Also, the form of the basal pad and its nuclei in the *Gomphine* and *Petalura* (apart from its actual size, shape, and position) is very closely similar to that of the Libellulidæ. These two points are of great importance when we come to consider the homologies of the gill-lamellæ in Libellulidæ.

Passing on now to the basal pads found in those *Æschnine* which have gills of the Foliate Type (*Æschna* and *Anax*), we have to notice two very important points of difference between them and those just studied above. Plate 22. fig. 26 shows a very typical cross-section taken from a foliate gill near the posterior end of the gill-basket in *Æschna brevistyla*. The outstanding feature of this section is the *occurrence of basal pads on both anterior and posterior faces of the folia*. Of these, that on the anterior face is the larger and longer, extending through a greater number of sections and showing everywhere a greater length along the gill-base. The second point is the more rounded form of the meganuclei (nu_1). These, though nearly always distinctly oval in transverse sections of the pad, are not of the elongate-oval form seen in the pads of *Austrogomphus*. Correlated with this rounder form of the meganuclei is the greater narrowness of the pad compared with its length, when contrasted with that of *Austrogomphus*. Micronuclei are also present, of the usual size and form.

In *Æschna* no part of the pad lies along the rectal circumference, but the whole mass stands up as a support for the base of the gill. Between the two pads lies a large mass of hypobranchial tissue (*hy*), while a very distinct cavity (*sp*) is often to be seen between the upper ends of the pads. At both ends the pads narrow to pass into the epithelial syncytium, which is *very deeply pigmented* (*pg*).

The last type of basal pad to be studied is that found throughout the Libellulidæ (Plate 22. fig. 27). This type differs from all those studied above in its intense localization into the form of separate oval or rounded swellings situated at the base of each lamella—a localization which is evidently correlated with the separation of the gills into distinct lamellæ.

Sadones, who studied this form in *Libellula*, made a peculiar error in stating the position of the pads on the lamellæ. He states that they lie near the axis of symmetry of each double series of lamellæ. By reference to

text-fig. 12, which is drawn from a photograph of an opened and cleared gill-basket of *Diplacodes hematodes*, and also to text-fig. 11 (*Synthemis*), it will be seen that this is by no means the case. On the contrary, each pad lies at the *outer anterior extremity* of the basal line of insertion of each lamella, and hence it is as far as possible from the axis of symmetry. This can also be easily verified in transverse sections, where the pads are always found lying on the *external* sides of their lamellæ (Plate 22. fig. 27). Now, since the basal line of insertion of each lamella lies in a slanting direction to the longitudinal axis of the gill-basket, with its inner end considerably *more anterior* than its outer, it follows that the external position of the pad in cross-sections indicates an actual position at the far end of the lamella and on its *anterior* side. Sadones's error obviously arose from his failing to distinguish clearly the two sets of lamellæ belonging to one double series. He has, by error, selected two adjacent hemibranchs from left and right respectively of two adjacent double series. Hence his axis of symmetry is really a line midway between two double series, and the position of the basal pads is correspondingly misdescribed.

Plate 22. fig. 27 shows a transverse section through one single series of lamellæ in *Cordulephya pygmæa*, enlarged from a portion of the complete section shown in fig. 24. Apart from their shape, the structure of the pads closely resembles that already described in *Austrogomphus*. The pad is more thickened than in *Æschna*, and the meganuclei are quite as elongated as those of *Austrogomphus*.

Sadones mentions the occurrence, in the basal pads of *Libellula*, of an occasional small nucleus, considerably smaller than the micronuclei, lying close up to the cuticle. I have also noticed similar nuclei in the pads of other Libellulidæ, but I may add that they are of very rare occurrence. One of them is shown in fig. 27, *nu*₅.

The very striking shape and colour of the basal pads in Libellulidæ is worthy of remark. On opening a gill-basket, the pads appear to be rows of buttons, of a rich transparent orange-brown colour, surrounded, in *Austro-cordulia*, by a ring of very dark brown. It is somewhat doubtful whether this colour actually belongs to the pad or to the underlying hypobranchial tissue. But, judging by its regularity of shape, I am inclined to attribute it to the pad itself, since the masses of hypobranchial tissue are of far less regular shape, and often project outwards below the bases of the pads.

The shape of the pad appears different according to the point from which it is viewed. When the gill-basket is everted, the pads at either end of a hemibranch are viewed somewhat end-on and appear as very elongate ovals. Towards the middle of the rows the convexity of the basket may throw the pads upward so that a more direct view is obtained. Viewed thus from above, they appear either circular or very convexly triquetral. It will thus

be seen that the pads are actually circular or nearly circular discs of fairly considerable thickness.

In the great majority of Libellulidæ the lamellæ are very numerous, more than twenty in a hemibranch, and very closely set. In these, usually the first two or three and the last four or five will be found to possess no basal pads at all. Occasionally also a pad may be missing here and there on any chance lamella near the middle of a hemibranch.

In the *Synthemini*, the number of lamellæ in a hemibranch is only twelve, or occasionally thirteen, and the lamellæ stand correspondingly further apart. Usually every lamella has a basal pad, but one may be absent here or there, especially on the first one or two lamellæ. The basal pads are comparatively enormous, at least twice as large as in other Libellulidæ (text-fig. 11), and their diameter may be as much as one-fourth of the whole length of the lamella. Their large size seems to be explicable in two ways, viz. :—

(1) Owing to the greater space between consecutive lamellæ, as compared with those of other Libellulidæ, there is a correspondingly greater need of basal supports. This is met by the greater size of the basal pads.

(2) The *Synthemini* are admittedly the most archaic of all Libellulidæ. If, then, we may assume that the localized basal pads of the Libellulidæ are derived from diffuse pads such as are found in gills of the Simplex System, we should naturally expect to find *less* localization in the more archaic *Synthemini*. The large pads of the latter, then, may be regarded as intermediate in formation between the diffuse pads in the Simplex System and the smaller localized pads of the rest of the Libellulidæ. It seems clear that the decrease in size of the pads is correlated with the increase in number of the lamellæ in each hemibranch and their greater closeness to one another.

THE HYPOBRANCHIAL TISSUE. (Text-fig. 16 ; Plate 22. figs. 25–27.)

In all forms of gill the space between the two gill-walls at the base of the gill-fold, bordered on one or both sides by the basal pad, is more or less completely filled with a mass of tissue in which the principal tracheæ of the gill run. This tissue was called by Chun and Faussek “connective tissue.” Sadones called it “adipose tissue,” but admitted that this name was faulty, since no trace of fat can be found in it. I propose to term it *hypobranchial tissue* (*hy*), a name which avoids any assumption as regards either structure or function, both of which are somewhat problematical, and simply indicates its position as lying in the space at the base of the gill.

This tissue differs from ordinary adipose tissue, not only in the absence of fat, but also in its staining qualities. With hæmatoxylin, it stains almost to an equal intensity with the basal pad ; so that, apart from its more irregular shape and the difference in the shape of its nuclei, it might be difficult to pick out at once in sections treated only with this stain. I find,

however, that this tissue takes a light but very characteristic eosin staining, which distinguishes it very clearly from the basal pad.

The structure of this tissue is the same in all forms examined, though the size and shape of the masses varies greatly. In all cases, definite cell-boundaries are not easily made out. The masses seem rather to consist of rounded lobules, sometimes with only one nucleus, but more often with several in each lobule. Usually the curved borders of the lobules show free and uncompressed, and there is very seldom seen any polygonization of the masses by mutual compression. The nuclei (*nu*₄) are numerous, of moderate size, rounded, darkly staining with hæmatoxylin, and with a fairly large and very distinct nucleolus.

Owing to its lobulate formation, the hypobranchial tissue never completely fills the space at the base of the gill-fold. It is not, however, therefore necessary to assign any particular function to the small space left at the top, just below the union of the two gill-walls. Sadones has termed this cavity a blood-space, and based upon it a theory that the blood plays some part in the physiological processes of respiration. Against this, I am able to state definitely that blood-corpuscles never occur in these cavities, and it seems very doubtful whether they have any regular communication with the hæmocœle at all. There is certainly no regular circulation of fluid in them, nor have I been able to trace in them either any regularity of form or any definite outlets to the hæmocœle.

The most definite fact about the function of this tissue is that it carries within its meshes, in all cases, the large trachea or tracheæ which enter the bases of the gill-folds. It is thus a support surrounding these main tracheæ, and I am inclined to regard this as its principal function. If we remember that the gases received from the water in the rectum must already have traversed the capillary loops and smaller tracheal branches before they reach these larger tracheæ, and that, by this time, these gases are simply in process of being transmitted to the main tracheal trunks for distribution throughout the body, we must see that the position of this tissue almost forbids us from ascribing to it any really important part in the physiological processes of respiration.

As to the origin of the hypobranchial tissue, I should like to state my belief that it will be found to be a special development from the supporting tissue to be found in large masses under the raised epithelium of the so-called "rectal glands" in the posterior portion of the rectum. The purview of this paper did not, of course, embrace a study of this portion of the rectum. But, in tracing back the posterior ends of the duplex gill-system in *Æschna brevistyla* (text-fig. 8), I had to follow the gill-basket in section right through into the region of the "rectal glands." Here I was struck by the immense masses of supporting tissue (*st.*) lying under the raised rectal epithelium. It seems probable that this tissue occurs in the recta of all

Odonate larvæ. In fact, I have already seen it in several genera of Zygoptera as well as in *Æschna*. Now we have already shown that the main gill-folds of the *Simplex System* are homologous with the "rectal glands." Their hypobranchial tissue, therefore, corresponds in position with the supporting tissue of the "glands."

The differences between the hypobranchial tissue and the supporting tissue of the glands are obvious enough. The former stains with eosin, the latter does not. After treatment with soap-alcohol, the former is unaffected, the latter has its contents extracted and shows up as a reticulated network of more or less empty spaces, much resembling the "skeleton" of the fat-body obtained by the same reagent. Thus, while the supporting tissue is closely analogous to true adipose tissue, and probably contains considerable stores of fat, the hypobranchial tissue is of a very different nature, and the contents of its lobules are impervious to the action of soap-alcohol. This suggests that the nature of the tissue has become chemically altered by the assumption of some new function connected with respiration, possibly the extraction of nitrogen from the gas passing along the tracheæ. That question, however, cannot be decided here, but must be left for future physiological investigations.

I have figured the hypobranchial tissue (*hy*) in the gills of *Dendroæschna* (text-fig. 16), *Austrogomphus* (Plate 22. fig. 25), *Æschna* (Plate 22. fig. 26), and *Cordulephya* (Plate 22. fig. 27). In *Dendroæschna* it is, like the basal pad, very narrow in cross-section. In *Austrogomphus* it usually fills up the hypobranchial space fairly completely; while in *Æschna*, where its mass is greater and more irregular, it often leaves a considerable space both above and below. In the Libellulidæ it may appear as a single row of lobules (possibly separate cells), or may be more irregular, with two or more layers of lobules in some cross-sections.

ONTOGENY OF THE GILLS IN THE LARVÆ OF *ÆSCHNA* AND *ANAX*. (Text-figs. 17-20.)

The development of the gills in the rectum of the growing larvæ of *Æschna* and *Anax* is a process of very great interest, and supplies the necessary evidence for linking up the structure of the *Simplex* and *Duplex Systems*.

A number of eggs of *Anax papuensis* were obtained by me in February last. Those that hatched out were taken on to the different larval instars as far as the fifth, two or three being killed immediately after ecdysis for the purposes of sectioning. Unfortunately the supply was not large enough to carry the investigation beyond the fifth instar. But the deficiency was here supplied by the discovery of a number of larvæ of *Æschna brevistyla* in very early stages, easily seen to correspond exactly with the fourth and fifth

instars of *Anax*. One of these was raised to the seventh instar. Later, a large number of *Anax* larvæ were found in stages which clearly corresponded to this seventh instar of *Æschna*, besides a few in the sixth instar. Many of these are still alive and at present are in the eighth or ninth instars (August). As the formation of the duplex foliate gill-type is practically completed by the seventh instar, these larvæ supplied me, *in toto*, with a complete account of the gradual formation of the gill-system.

We shall divide our account of the ontogeny of the gills into three sections, as follows:—

- (1) The state of the gill-basket at the time of hatching, and the changes that take place immediately afterwards.
 - (2) A description of the gill-basket and its tracheal supply during the second instar*.
 - (3) The gradual development of the duplex system of gills.
- (1) *The state of the gill-basket at the time of hatching, and the changes that take place immediately afterwards.* (Text-figs. 17–19.)

The young *Anax* larva emerges from the egg very rapidly, covered with two cuticles. The *first instar*, or *pronymph* stage, lasts only a very short period, ranging from a few seconds to a little over a minute. Then the outer cuticle is rapidly cast off, and the larva emerges fully equipped for its life-struggle, with its powerful mask formed ready for capturing its prey. This is the *second instar*.

At the moment of emergence from the pronymphal skin, the pulsating organ of the head is still beating, though it subsides shortly afterwards. The tracheæ of all the posterior region of the body contain no air and are quite invisible, except the large dorsal trunks, which can be faintly seen. The dorsal tracheæ, in the region anterior to the midgut, are seen to be filled with air, which appears like a black continuous rod travelling steadily backwards along the tracheæ. At the moment when the larva gets free from the pronymphal skin, the air has reached to the level of the midgut. Thence it travels fairly quickly backwards, filling up and outlining in black each tracheal branch which it meets with in its course. I am inclined to connect this regular filling of the tracheæ with air, from some point in the anterior part of the body, with the pulsations of the head organ, which can be seen to stop about the time that the tracheal system becomes filled with air. The point, however, needs further elucidation.

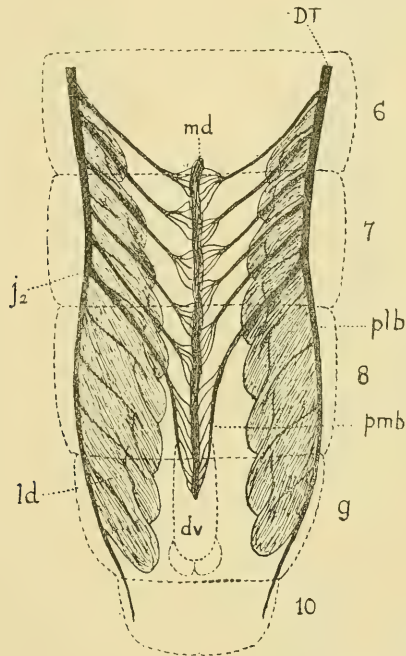
At first, there is no sign of gills in the rectum. But as the air travels backwards to the rectum, six longitudinal gills begin to be outlined in very regular and beautiful fashion. These gills are thrown into folds or undulations in which numerous tracheal loops occur. The air enters each loop in

* Here, as elsewhere, I consider the so-called “pronymph” stage to be definitely the *first instar*, so that the larva commences its free existence in its *second instar*.

turn and travels round it completely, until the whole series of folds with their contained loops is clearly outlined by the air within. Regular movements of contraction and expansion of the rectum take place from this time onward.

(2) *A description of the gill-basket and its tracheal supply during the second instar.*

We have seen that the original air-supply of the gill-basket is not derived from water drawn into the rectum, but comes from some source in the anterior portion of the larva, and enters the gills through the main tracheal trunks. Let us now study the formation of the gill-basket as it is to be seen in the transparent larva shortly after the first ecdysis.



TEXT-FIG. 17.—*Anax papuensis*, Burm.

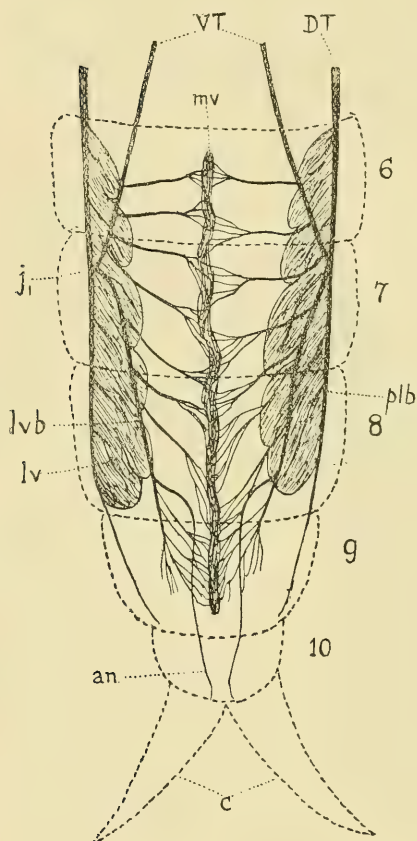
Dorsal view of gill-basket of newly-hatched larva. Camera-lucida drawing. ($\times 180$.)

DT, dorsal tracheal trunk; *dv*, dorsal vessel or heart; *j₂*, second junction; *ld*, latero-dorsal gill-fold; *md*, mid-dorsal gill-fold; *plb*, postero-lateral branch of DT; *pmb*, postero-medial branch of same. 6-10, abdominal segments.

The six longitudinal gill-folds lie in the rectum in positions corresponding to the numbers 2, 4, 6, 8, 10, 12 on the clock-face. They are not all of the same length, the ventral gill-fold and the two latero-dorsals (*i. e.* the three gills corresponding to the numbers 2, 6, 10 on the clock-face) being

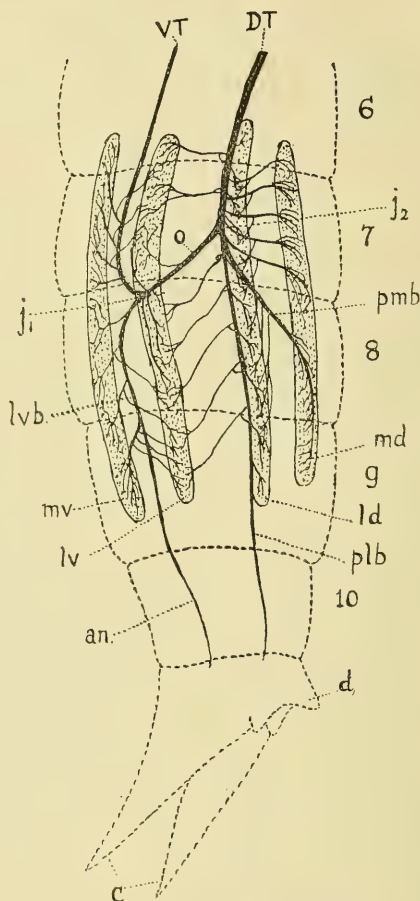
considerably longer than the other three, and the dorsal gill being the shortest of all. The lengths of the gills are not constant, for, during the movements of expansion and contraction of the rectum, not only their actual lengths, but also their positions with respect to the abdominal segments, become slightly altered.

Each gill-fold is thrown into from six to nine very distinct undulations,



TEXT-FIG. 18.—*Anax papuensis*, Burm.
Ventral view of gill-basket of newly hatched larva. Camera-lucida drawing. ($\times 180$.)

an, anal branch trachea; *c*, cerci; *j*₁, first junction; *j*₂, second junction; *lv*, latero-ventral gill-fold; *lvb*, latero-ventral branch of DT; *mv*, mid-ventral gill-fold; VT, visceral tracheal trunk. Other references as in text-fig. 17.



TEXT-FIG. 19.—*Anax papuensis*, Burm.
Lateral view of gill-basket of newly hatched larva. Camera-lucida drawing. ($\times 180$.)
d, appendix dorsalis; *o*, oblique trachea.
Other references as in text-figs. 17–18.

in each of which a number of complete capillary loops can be clearly seen. The epithelium of the gills appears to be of a slight yellowish tinge.

The study of the two pairs of lateral gills is not easy, as it is difficult to persuade the larva to rest in suitable positions. However, I was able to make camera-lucida drawings of a larva, not only from the dorsal and ventral aspects (text-figs. 17, 18), but also in profile (text-fig. 19). The actual distribution of tracheæ in the gill-basket was most carefully studied in the case of dorsal and ventral gills, so that I will deal with these first.

From the dorsal aspect (text-fig. 17) the dorsal gill-fold is seen to be a long undulating strand of tissue lying in the middle line. From the main dorsal trunk (DT) on each side, six efferent tracheæ come off slantingly and run towards the gill-fold. Just before reaching it, each efferent trachea divides into several secondary branches. These branches pass into the gill vertically downwards in alternate sets to right and left. Hence arises that slight undulatory outline of the base-line of the gill-fold; for each set of tracheæ may be supposed to exert a very slight pull on the gill towards one side, so that each set enters the gill by a slight convexity on its own side. It will thus be seen that the system of gills present in the larva of *Anax* soon after hatching is very different from that seen in the older larva. It is, in fact, a primitive *Simplex Gill-system* of *Undulate Type*, very similar to that found in the well-grown larvæ of *Petalura*, *Cordulegaster*, and *Austrogomphus*, but without any system of cross-folds. This fact fixes the *Undulate Simplex* type of gill definitely as the *most primitive* of all the types studied in this paper.

The last of the six efferent tracheæ (*pmb*) on each side of the dorsal gill is longer and thicker than the preceding five. Instead of breaking up into a few secondary branches, it turns to run posteriad alongside the gill for some considerable distance, giving off at short intervals some eight or nine secondary branches. Thus these last two efferent tracheæ come to supply between them nearly one-third of the whole length of the gill. By referring to text-fig. 17, it will be seen that these tracheæ, which I have designated the *postero-median branches* (*pmb*) of the main dorsal trunk, correspond exactly with the strong trunks of the same name which supply the narrow posterior portion of the gill-basket in the full-grown larva of *Æschna brevistyla*.

Turning now to the ventral gill-fold (text-fig. 18), we notice a very similar arrangement of efferent tracheæ supplying the gill alternately from left to right. There are, however, some important differences. Corresponding to the greater length of this gill-fold, we find altogether *eight* efferent tracheæ on each side. Of these, the first four on each side arise from the corresponding *visceral trunk* (VT). Just posterior to the fourth, however, the visceral trunk bends round upwards to enter the *oblique branch* (*o*) of the main dorsal trunk at the point which I have called the *first junction* (*j₁*).

Arising also from this junction, a strong trachea, the *latero-ventral branch* (*lvb*), passes posteriad to the region of the anus. From this trachea the remaining four efferents are given off to the ventral gill-fold. The last efferent of all appears to be a straight continuation of *lvb*, and gives off numerous secondary tracheæ to the ventral gill-fold. The anal branch (*an*) comes off from *lvb* at the point where we consider the last efferent to begin, curves inwards towards the middle line, and then passes to the end of the tenth segment.

During the movements of respiration, the oblique branch *o* swings to and fro, so that its angle of inclination to the dorsal trunk constantly varies. Hence the position of the first junction (j_1) is always altering. Sometimes it is seen to lie just under the suture between segments 7 and 8 (text-fig. 19), sometimes it appears in the anterior portion of segment 7 (text-fig. 18). The structure and size of this oblique branch strongly suggests that both the visceral trunk and the latero-ventral branch are true outgrowths of the main dorsal system, and probably receive their air in the first instance via the oblique branch. I was not, however, able to observe this taking place during the very short period in which the air was travelling along the tracheæ.

When we turn to the lateral gills (text-fig. 19) we can see that each gill-fold is supplied by two sets of efferent tracheæ, just as in the case of the dorsal and ventral gill-folds. In the case of the latero-dorsal gill-folds, these sets are both derived from the dorsal trunks, but in different manners. My observations on their distribution are not so complete as I could wish, but I was able to make out the following points. From the point where the large postero-median branch (*pmb*) comes off, the dorsal trunk runs posteriad almost to the anal end of the larva. This point I have termed the *second junction* (j_2). It marks also the branching off of the oblique branch (*o*) from the main dorsal trunk. One set of efferent tracheæ, numbering eight or nine, comes off from the whole length of the main dorsal trunk in this region to supply the dorso-lateral gill-fold, while a second appears to branch off from the efferent tracheæ of the dorsal gill-fold, close to their points of origin. Owing to the great foreshortening of these tracheæ in lateral view, their exact distribution was difficult to make out; while, in dorsal view, the laterally-lying position of the latero-dorsal gill-folds made it impossible to study their points of entry into the gill at all.

With regard to the latero-ventral gill-folds, the same difficulties were met with, but in a less degree, as the amount of foreshortening was less. A set of seven or eight efferent tracheæ enters these gills on their dorsal side, and arises from the dorsal trunk. They seem to be united near their bases with the lower set of efferents to the latero-dorsal gill-folds—that is to say, the dorsal trunk on each side gives origin to a set of tracheæ, each of which branches into two near its base, one branch passing to the latero-dorsal gill-fold, the other to the latero-ventral. The other set of tracheæ supplying

this latter gill arise partly from the visceral trunk and partly from the latero-ventral branch, from the same stems as the efferents of the ventral gill-fold ; they also are seven or eight in number.

It will be seen from the above description that, although the form of the gill-folds is very simple, their tracheal supply is very complicated. It may be best understood by ignoring, for the moment, the complications introduced by the branchings of the tracheal trunks at j_1 and j_2 , and confining our attention to the part of the gill-basket anterior to these two points. We may then state the position as follows :—

Each dorsal trunk gives off alternately *two* sets of primary efferent tracheæ, a more dorsal set and a more ventral set. Each trachea of the more *dorsal* set divides into two branches, one of which becomes a secondary efferent trachea of the dorsal gill-fold, the other a secondary efferent of the latero-dorsal gill-fold. Each trachea of the more *ventral* set also divides into two branches, one of which becomes a secondary efferent of the latero-dorsal gill-fold, the other a secondary efferent of the latero-ventral gill-fold.

Each visceral trunk, on the other hand, gives off *only one* set of primary efferent tracheæ. Each of these tracheæ divides into two branches, one becoming a secondary efferent of the latero-ventral gill-fold, the other a secondary efferent of the ventral gill-fold.

In other words, the two dorsal trunks between them supply the whole tracheal system for the dorsal and two latero-dorsal gill-folds, and the upper half of that for each of the latero-ventral gill-folds. The two visceral tracheæ between them supply the whole tracheal system for the ventral gill-fold and the lower half of that for each of the latero-ventral gill-folds.

If, now, we admit the trachea *lvb* as portion of the visceral system (with which it becomes continuous in later stages), we may say that the dorsal trunks account for the *upper two-thirds* of the tracheal system of the rectum, the visceral trunks for the *lower one-third*. The *proportions* are made up as follows :—

Gill-fold.	Branches from Dorsal Trunks.	Branches from Visceral Trunks.
Dorsal	2	0
Right latero-dorsal ..	2	0
Left latero-dorsal	2	0
Right latero-ventral ..	1	1
Left latero-ventral ..	1	1
Ventral	0	2
Total	8	4

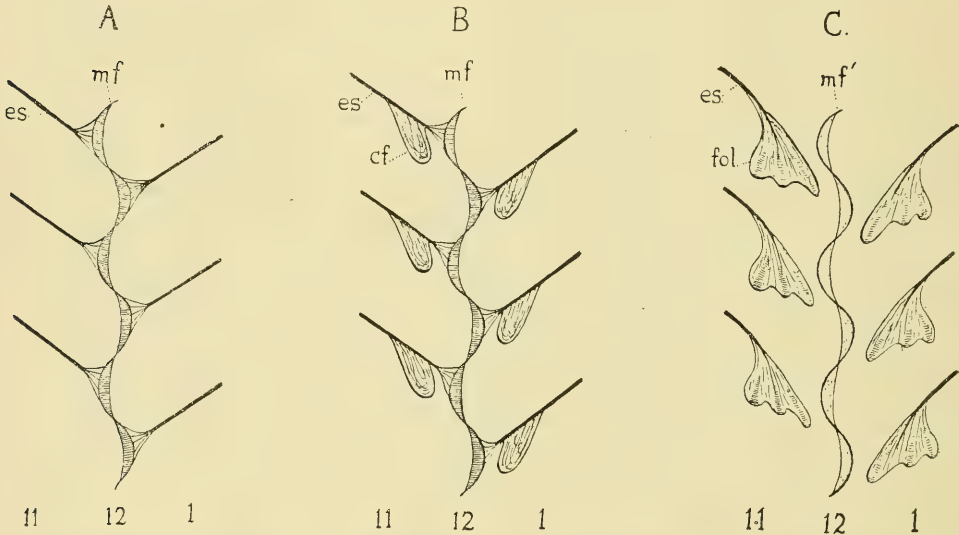
(3) *The gradual development of the duplex system of gills.*
(Text-fig. 20.)

Passing now to the third instar, we notice the following advances made in the gill-basket of a transparent larva examined soon after ecdysis :—

All the gill-folds show deeper undulations, and the tracheal loops are more abundant.

The efferent tracheæ are considerably stouter.

There is thus very little advance on the stage seen in the second instar. When, however, we come to the fourth instar (text-fig. 20, B), we find a very interesting stage in the development. Confining our studies for the



TEXT-FIG. 20.—Diagrammatic representation of dorsal portion of gill-basket, viewed from above, to show the development of the Duplex System from a primitive Simplex System. Taken from camera-lucida drawings immediately after ecdysis. A. From *Anax papuensis*, Burm., 2nd Instar; primitive Simplex Main Fold. B. From *Anax papuensis*, Burm., 4th Instar; development of cross-folds. C. From *Æschna brevistyla*, Ramb., 7th Instar; abortion of tracheal supply to main fold, and growth of cross-folds to form foliate gills of the Duplex System (7th Instar of *Anax* the same, with papillæ). *cf*, cross-fold; *es*, secondary efferent trachea; *fol*, folia; *mf*, main fold; *mf'*, ditto, aborted; 11, 12, 1, positions on clock-face.

present to the dorsal gill-fold, we notice the following very interesting points :—

The undulations of the main gill-fold are deep and very regular. Each secondary efferent trachea gives off its branch tracheæ to the fold along the crest of a wave, *i. e.* to that portion of the fold which is convex to it. From each secondary efferent trachea, close to the main fold, there rises up

(projecting into the rectal cavity in a slanting direction, somewhat posteriad) a small but very distinct oval leaflet filled with tiny tracheal loops. These leaflets are unmistakably similar both in appearance and position to the *lamellæ* of the Libellulidæ. They also correspond fairly closely to the *cross-folds* in the *Simplex System* of gill-folds.

With these leaflets in front of us, we stand at the parting of the ways between the Undulate Simplex and the Lamellate Duplex Types. If the leaflets, in their further development, joined up to the main fold as a series of supports, we should obtain the *Undulate Simplex* type of gill-fold seen in *Petalura*, *Cordulegaster*, and *Austrogomphus*. If, on the other hand, the main folds became aborted, and the leaflets developed into lamellæ of considerable size, we should then have the *Lamellate Duplex* type seen in the Libellulidæ.

In order to study the formation of the gill-basket at the fourth instar more fully, several larvæ of *Æschna* and *Anax* were taken immediately after ecdysis and prepared for sectioning. Text-fig. 1 shows a cross-section through a larva of *Æschna brevistyla* at about the middle of the gill-basket. Owing to the semi-collapsed state of the main folds, especially on the ventral side, the undulations are flattened down, and several are cut through in the same section. This accounts for the zigzag course of the sections across these main folds.

Between each pair of main folds two small triangular prominences (*cf*) are to be seen, appearing as slight evaginations of the rectal epithelium. Their size depends, of course, on whether the particular section studied cuts the leaflets through their middle or near one of their edges. The largest cross-section of a leaflet seen in this series of sections was somewhat larger than the two marked *cf* in the figure.

A careful examination of sections of a larva in the *third instar* shows that these leaflets really begin to develop at that stage as tiny outpushings of the rectal epithelium, between, and fairly close up to, the main folds. They are not, however, large enough to be noticed in an examination of the living larva. Sections of larvæ in the second instar, on the other hand, show no sign of these outpushings. The only other noticeable differences between sections taken from larvæ of the second, third, and fourth instars are the gradual increase in definiteness and depth of the undulations in the main folds and the rapid increase in size in the larger tracheæ.

From the fourth instar onwards the small leaflets rapidly increase in size, while numerous tracheoles are seen to ramify in them. On the other hand, the tracheæ entering the main folds become inconspicuous and are soon lost to view, in the live larva, in the mass of yellowish-brown epithelium which seems to be raised up along the course of the original main folds during the rapid growth of the leaflets. At the sixth instar these leaflets are very

clearly to be distinguished by their abundant tracheation and by the gradual appearance of a darkish pigmentation localizing their position.

Larvæ of both *Æschna* and *Anax* were taken and sectioned at the seventh instar (text-fig. 20, C). Also, the gill-baskets of others of the same age were opened, and selected portions of the gills photographed, when a very interesting result was noticeable. In both genera the foliate type of gill was completely established by the development of undulations on the original leaflets, which by now project into the rectum in the form of a series of definite foliæ closely resembling those seen in the full-grown larva of *Æschna*, but not so deeply pigmented. But, in *Anax*, little bundles of developing papillæ were to be seen projecting outwards from the free edges of the foliæ.

In order to trace back the origin of these papillæ, I took the only remaining larva of *Anax* which I still possessed in the *sixth* instar, and dissected it carefully. On opening the gill-basket I found, at the extreme edges of the foliæ, tiny groups of four or five papillæ grouped together in a very immature stage of development, with here and there a small swelling indicating the beginning of papilla-formation along other parts of the leaf-edge. The papillæ are, at the first, small rather pyramidal tubercles, containing no tracheæ. As they increase in length (their area in cross-section near the base remaining fairly constant), the tracheal loops lying immediately beneath them are as it were *sucked up* out of their course into the papillæ. Finally, they become long enough to resemble the finger of a glove, with the capillary loops rising up well into their interior. At the sixth instar I did not notice a single papilla fully formed, and very few indeed had tracheal loops in them. At the seventh instar a large number of the papillæ were fairly complete, others were in all stages of development.

The further development of the typical papillo-foliate gill-type in *Anax* is very rapid. During the seventh instar the foliæ tend to curve over posteriorly along their free edge, while numerous papillæ arise at all points of the curve. At the eighth instar this curved folia already bears a very close resemblance to the *basal hump* of the full-grown larva, and is very deeply pigmented. A series of these foliæ taken along the free edge of a hemibranch in semi-profile, at the eighth instar, is shown in Plate 19. fig. 8. As will be seen, they differ little from the condition seen in the adult (Plate 21. fig. 16).

PHYLOGENETIC CONCLUSIONS. (Text-fig. 21.)

We are now in a position to review our study of the gill-basket with a view to stating the phylogenetic conclusions to which it points. These may be summarized as follows :—

1. The most primitive type of gill-basket to be found in present-day Anisopterid larvæ is undoubtedly the *Undulate Type* in the *Simplex System*.

This is shown by two facts :—

(a) The *Undulate Type* is found in the mature larvæ of just those very genera which are universally acknowledged, by reason of the number of other archaic characters which they possess, to be the most primitive forms of Anisoptera still existing (*Petalura*, *Cordulegaster*, *Austrogomphus*).

(b) The *Undulate Type* also occurs in the young larvæ of *Æschna* and *Anax*, which later on develop a *Duplex System* of gills of the *Foliate Type*.

2. The main longitudinal gill-folds in the Simplex System are homologous with the so-called "rectal glands." This is also shown by two facts :—

(a) Both occur as six longitudinal eversions of the rectal wall in the positions 2, 4, 6, 8, 10, 12 on the clock-face.

(b) The aborted main folds in the well-grown larva of *Æschna* can be followed back into the "rectal glands," of which they form the anterior portion.

3. The cross-folds in the Simplex System arise, ontogenetically, later than the main folds. They are therefore probably less archaic in origin than the main folds.

4. The *Papillate Type* of gill in the Simplex System is a remarkable specialization from the more primitive *Undulate Type*. It may be regarded as the highest expression of the Simplex System.

5. The *Duplex System* arose from the more primitive *Simplex System* (early *Undulate Type*) by gradual suppression of the main folds and by the elevation of the function of the cross-folds to act as the principal gills of the system. This is shown by the two following facts :—

(a) In the ontogenetic development of the *Duplex System* in *Æschna* and *Anax* a gradual suppression of the main folds and upgrowth of the cross-folds leads to the development of the *Foliate Type* of gill from the *Undulate Type* possessed by the young larva.

(b) The separate gills of the hemibranchs of the *Duplex System* correspond exactly, in their position and tracheal supply, with the cross-folds in the *Simplex System*.

6. The fact that the middle line or axes of symmetry of the holobranchs in the *Duplex System* occupy the positions 1, 3, 5, 7, 9, 11 on the clock-face, cannot be used as an argument against the homology of the rectal gills with the "rectal glands," as Sadones has used it. The change of position is clearly explained by 5.

7. The *Implicate Type* of the *Duplex System* is the most archaic type still extant in that system. This is shown by :—

(a) Its resemblance in details to the *Undulate Type*.

(b) The very weak development of the basal pads.

8. The *Implicate Type* does not, however, lie exactly along the direct

phyletic line of ascent of the *Foliate Type*, rather the latter, as formed in *Æschna* and *Anax*, must be considered to have arisen from a somewhat simpler development of the *Implicate Type*.

9. The *Foliate Type* represents the highest development of the *Duplex System* within the *Æschninae*. The *papillo-foliate* sub-type is a specialization from the *normal foliate* sub-type of *Æschna*.

10. The *Lamellate Type* is an isolated type within the *Duplex System*, of very high specialization, but undoubtedly also of very great antiquity. Its point of phyletic union with the other gill-types must be sought for far back in the early days of the *Undulate Type*, before the main folds attained any great development. In the formation of the *Lamellate Type* the main folds became completely suppressed, the cross-folds became highly developed as gill-lamellæ, and the basal pads underwent a correlated localization as flat supporting discs and became deeply coloured.

11. The number of undulations and corresponding sets of cross-folds corresponded primarily with the number of primary efferent tracheæ developed, and was probably at the first from six to nine. This number early increased to twelve, the number still found in the mature larvæ of *Petalura*, *Cordulegaster*, *Austrogomphus*, *Hemigomphus*, *Anax*, and *Synthemis*. Further development increased this number up to as much as thirty in highly specialized cases (e. g., *Diplacodes*).

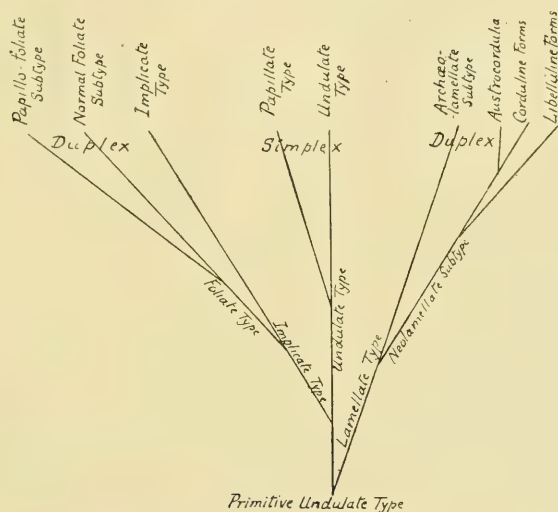
12. Within the *Lamellate Type* only minor variations of structure occur. We can perhaps distinguish as sub-types the *Archilamellate* gills in the *Synthemini* and the *Neolamellate* gills in the rest of the *Libellulidæ*. Within the latter sub-type some minor differences separate the *Corduliinae* from the *Libellulinae*. The latter subfamily shows the higher specialization, culminating in *Diplacodes*. *Austrocordulia* has struck out a side-line of specialization by an attempt to develop papillæ. *Cordulephya* appears, as in other larval characteristics, to belong definitely to the *Eucorduliini*.

The above twelve conclusions are illustrated by the phylogenetic diagram in text-fig. 21.

The value of the evidence afforded by the gill-structure in elucidating the general phylogeny of the Anisoptera is considerable, and tends to strengthen the views already put forward by recent workers in that field. In pointing to *Petalura* and *Cordulegaster* as the most archaic of living Anisoptera, it agrees with the conclusions already obtained both from Palæontology and from other branches of the Comparative Morphology of both larva and embryo. The greater antiquity of *Austrogomphus* as compared with *Hemigomphus*, and hence also with *Gomphus* and *Onychogomphus*, is a very interesting point, though only of secondary importance. Passing on to the *Æschninae*, it is much to be regretted that a larva of the archaic tribe *Petaliini* cannot be obtained for study, since this will almost certainly either give us the missing link between the *Implicate Type* and the *Undulate Type*,

or provide us with another new type. In passing, it may be remarked that, if the larva of the *Petaliini* can be shown to possess gills of the *Duplex System*, that fact will practically decide once and for all the claim of this group—already a strong one—to be included in the true *Æschninae*. The study of the *Implicate Type* as compared with the *Foliate Type* confirms the view already held that the *Brachytronini* (*Implicate Type*) are more primitive than the *Æschnini*, though they have branched away somewhat from the line of ascent of the latter. The study of the *Foliate Types* marks out *Æschna* and *Anax* as naturally closely allied, and also confirms the view already held that *Anax* as now constituted was formed by rapid cænogenetic specialization from the older *Æschna*-stock.

The most valuable phylogenetic evidence afforded by our study is undoubtedly that which concerns the Libellulid stock, whose origin is still



TEXT-FIG. 21.—Phylogenetic Diagram.

a matter of doubt. The form of the gill-basket points at once to the two facts that they are not only a very highly specialized side-branch from the main line of Anisopterid advance (which we may take to be represented by the upgrowth of the *Æschninae* from Undulate-Typed ancestors), but that the origin of this highly successful stock goes very far back, almost to the very root-beginnings of Anisopterid history. By no other supposition than this can we explain the complete suppression of the underlying *Undulate Type* even as early as the third or fourth instar in the Libellulid larva. Further light may be thrown on this by studying the gill-basket in the newly-hatched Libellulid larva; we may even have to examine its formation within the embryo. Even within the evidence before us, we are able to single out

Cordulegaster (on its totality of larval characteristics) as the nearest living relative of this huge family. But the gap between *Cordulegaster* and the Libellulidæ is still a large one. This gap is considerably lessened if we compare *Cordulegaster* with *Synthemis*, for the gill-basket of the latter agrees with that of the former in possessing only the archaic number of twelve sets of cross-folds, albeit they are wholly disguised as lamellæ. The large size also of the basal pads indicates to us a way of approach between the localized pads of Libellulidæ and the generalized pads of other Anisoptera. It seems probable, perhaps, that we shall in the end have to admit that the origin of the Libellulidæ is quite lost to us in the mists of antiquity, unless some fortunate fossil find in the still unworked fresh-water beds of the Trias-Jura in Australia may yet hold the key to the puzzle.

Finally, our study emphasizes the homogeneity and closeness of descent of the two subfamilies forming the Libellulidæ. The characters separating the *Corduliinæ* from the *Libellulinæ* are everywhere of a lower order of value than those separating other subfamilies. Yet there can be no doubt of their distinctness. It seems, too, that much of the difficulty of separating the two may be due to convergence between their highest members. Certainly the difference between *Synthemis* and, say, *Libellula* is very much more marked than that between the *Eucorduliini* and *Trameini*, which are regarded at present as the highest members of the two subfamilies. We may, perhaps, have to alter our views later on as to the position of the *Trameini*, and assign to the *Sympetrini*—those Passerines amongst Odonata—the pride of place in the Libelluline stock.

In conclusion, if we had to select from amongst all the forms studied the two most highly specialized larvæ, we should undoubtedly choose *Anax* and *Diplacodes*, standing at the extreme ends of development of their respective branches. To select from these two the most highly specialized of all Anisopterid larvæ would be no easy task; but I am inclined to award the palm to *Anax*, which seems to me to combine in the highest degree all those qualities essential to the carnivorous aquatic larva.

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EXPLANATION OF THE PLATES.

PLATE 18.

(Simplex and Implicate Types. Photomicrographs.)

- Fig. 1. *Austrogomphus ochraceus*, Selys. Undulate Simplex Gill, from full-grown larva.
 2. *Hemigomphus heteroclitus*, Selys. Papillate Simplex Gill, from nearly full-grown larva.
 3. *Austroæschna multipunctata*, Martin. Implicate Duplex Gill, from full-grown larva.
 4. *Dendroæschna conspersa*, Tillyard. Ditto.

(All figures $\times 60$.)

PLATE 19.

(Foliate Types. Photomicrographs.)

- Fig. 5. *Æschna brevistyla*, Ramb. Normal Foliate Gills, from anterior portion of gill-basket of a larva about the 10th instar.
 6. *Æschna brevistyla*, Ramb. Ditto, from posterior portion of gill-basket of same larva.
 7. *Anax papuensis*, Burm. Papillo-foliate Gills, from larva at 8th instar.
 8. *Anax papuensis*, Burm. The same, seen in profile, from larva at 7th instar.

(All figures $\times 60$.)

PLATE 20.

(Lamellate Types. Photomicrographs.)

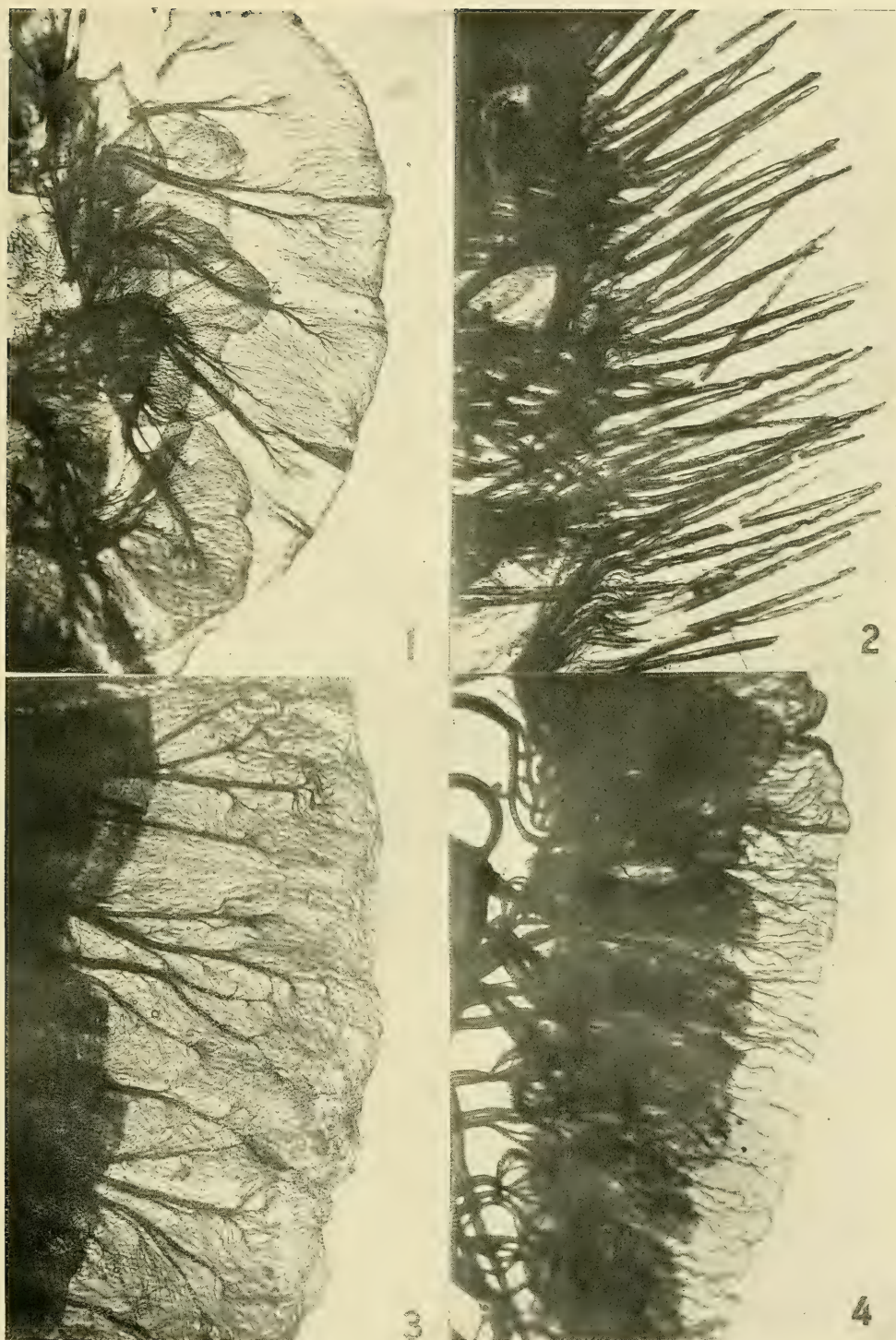
- Fig. 9. *Metathemis guttata*, Selys. Lamellate Gills, from full-grown larva.
 10. *Synthemis macrostigma*, Selys. Ditto.
 11. *Austrocordulia refracta*, Tillyard. Ditto.
 12. *Hemicordulia tau*, Selys. Ditto.

(Fig. 10, $\times 75$. Figs. 9, 11, 12, $\times 60$.)

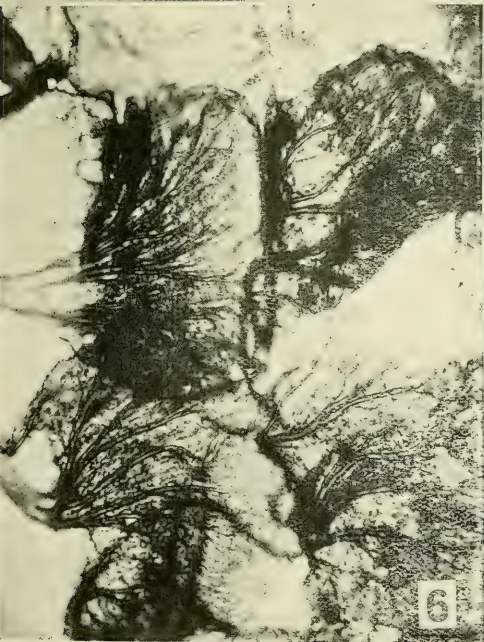
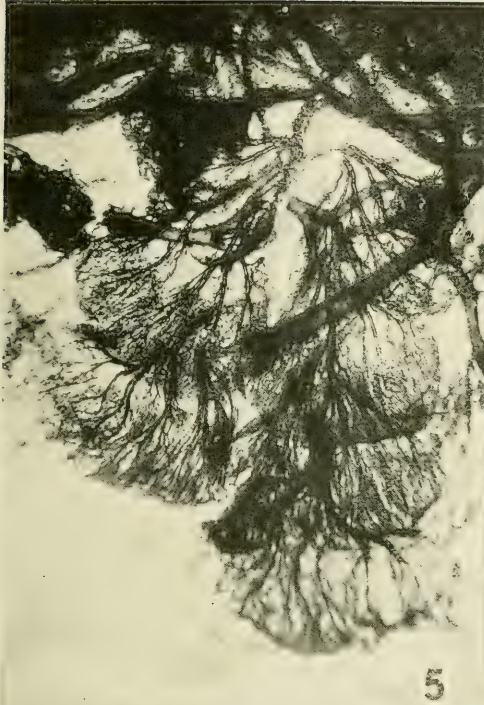
PLATE 21.

(Miscellaneous Photomicrographs.)

- Fig. 13. *Orthetrum caledonicum*, Br. Lamellate Gills, from full-grown larva. ($\times 60$.)
 14. *Orthetrum caledonicum*, Br. Ditto. ($\times 16$.)
 15. *Æschna brevistyla*, Ramb. Normal Foliate Gills, from full-grown larva (posterior portion of gill-basket). ($\times 16$.)
 16. *Anax papuensis*, Burm. Papillo-foliate Gills, from full-grown larva. In profile. ($\times 16$.)
 17. *Austrogomphus ochraceus*, Selys. Portions of two holobranchs, to show cross-folds. ($\times 16$.) Compare text-fig. 2.



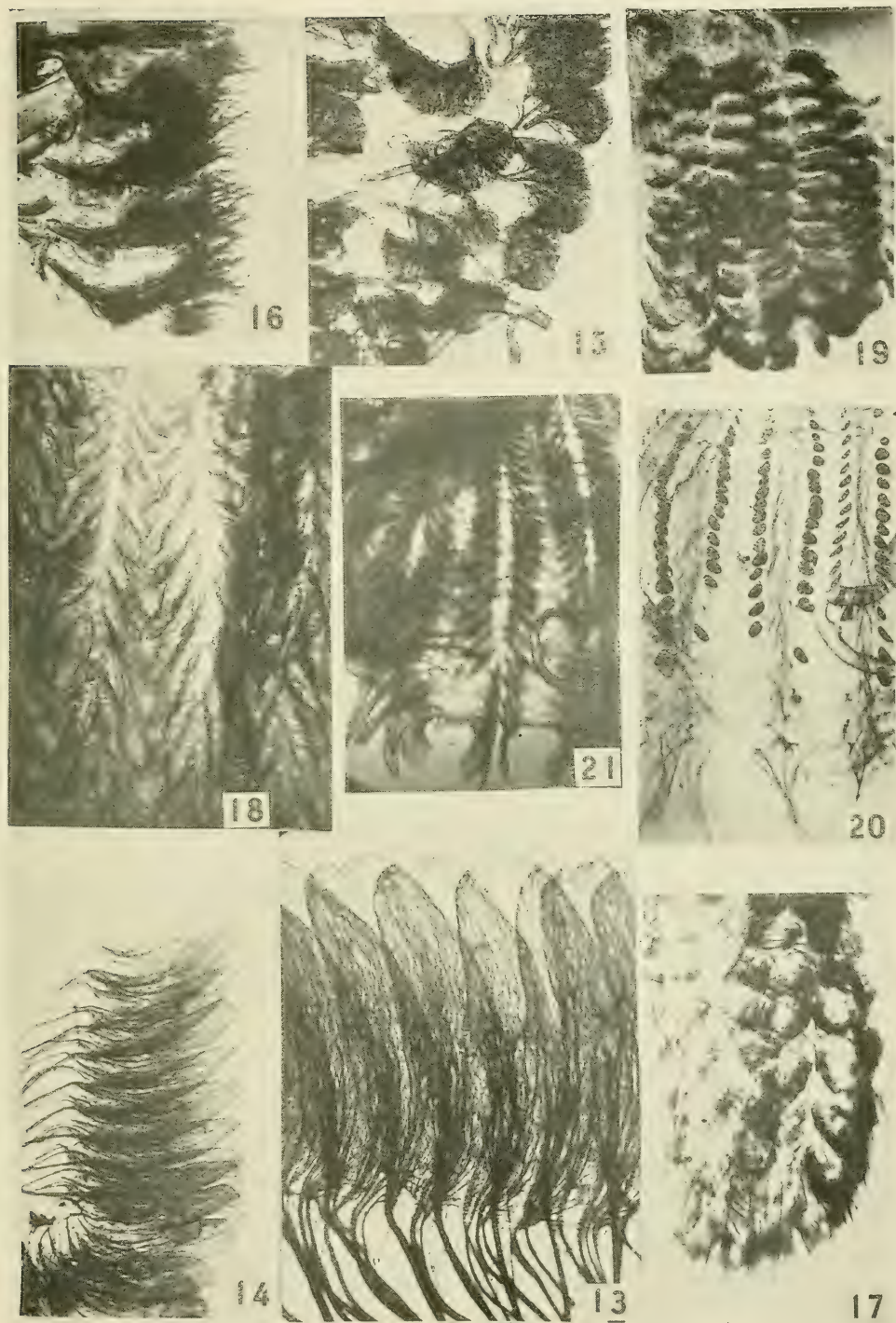
RECTAL BREATHING APPARATUS.



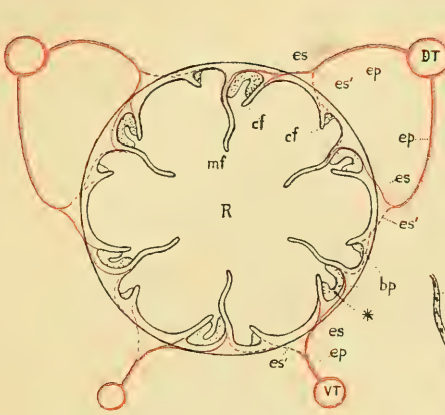
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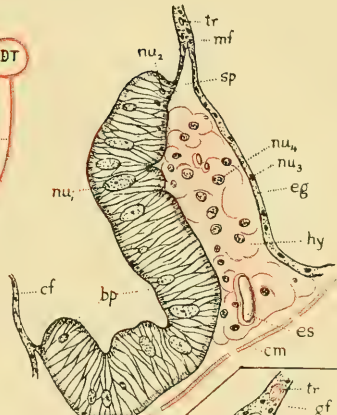
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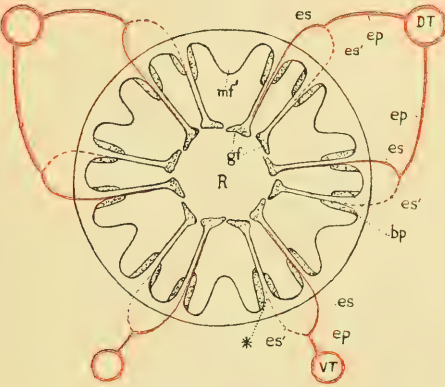
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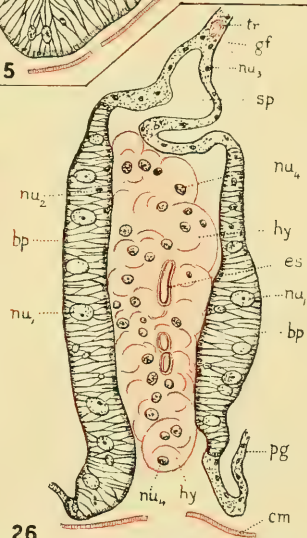
22 *Austrogomphus ochraceus*



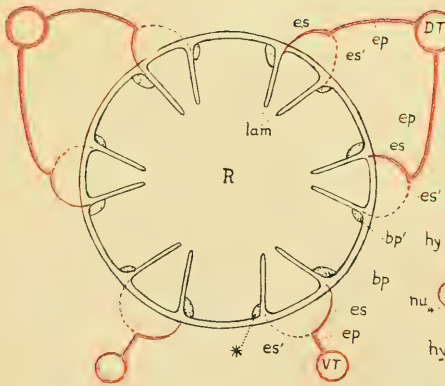
25



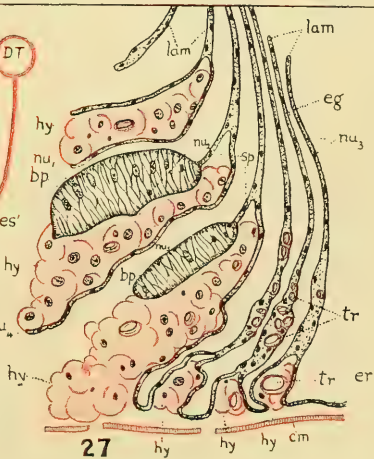
23 *Aeschna brevistyla*



26



24 *Cordulephya pygmaea*



27

Grout, Sc.

- Fig. 18. *Austrogomphus multipunctata*, Martin. Portions of three holobranchs. ($\times 16$) Compare text-fig. 5.
19. *Anax papuensis*, Burm. Three complete holobranchs. ($\times 16$) Compare text-fig. 9.
20. *Austrocordulia refracta*, Tillyard. Portions of three holobranchs. ($\times 16$) Notice basal pads and absence of pigmentation.
21. *Diplacodes hæmatodes*, Burm. Portions of three holobranchs. ($\times 16$) Notice basal pads and deep pigmentation. Compare text-fig. 12.
- (Figs. 17, 18, 19, 21 are photographs of portions of the whole mounts from which the text-figures 2, 5, 9, 12 respectively were also taken.)

PLATE 22.

(Transverse sections of Gill-baskets and Basal Pads.)

- Fig. 22. *Austrogomphus ochraceus*, Selys. Diagrammatic. T. S. through gill-basket. ($\times 46$)
23. *Æschna brevistyla*, Ramb. Ditto. ($\times 16$)
24. *Cordulephya pygmaea*, Selys. Ditto. ($\times 22$) Only those lamellæ are shown whose basal pads are actually cut, in this section, nearest their middle lines. The rest are omitted. Contrast fig. 27.
25. *Austrogomphus ochraceus*, Selys. Much enlarged T. S. through base of gill marked * in fig. 22. ($\times 305$.)
26. *Æschna brevistyla*, Ramb. Much enlarged T. S. through base of gill marked * in fig. 23. ($\times 135$.)
27. *Cordulephya pygmaea*, Selys. Much enlarged T. S. through base of lamellæ actually cut through near point marked * in fig. 24. ($\times 220$.)

Reference letters:—

bp, basal pad; *bp'* (fig. 24), the same, cut farther from its middle line; *cf*, cross-fold; *cm*, circular muscle-layer; *DT*, dorsal tracheal trunk; *eg*, epithelium of gill; *ep*, primary efferent trachea; *er*, epithelium of rectum; *es*, secondary efferent trachea; *es'*, the same (dotted line), not in the true level of the section; *gf*, gill-folia; *hy*, hypobranchial tissue; *lam*, gill-lamella; *mf*, main longitudinal gill-fold; *mf'* (fig. 23), the same, aborted and functionless; *nu₁*, meganucleus of basal pad; *nu₂*, micronucleus of same; *nu₃*, nucleus of gill-epithelium; *nu₄*, nucleus of hypobranchial tissue; *nu₅* (fig. 27), minute nucleus in basal pad; *pg* (fig. 26), highly pigmented gill-epithelium; *R*, rectal cavity; *sp*, space between gill-walls, above hypobranchial tissue; *tr*, trachea; *VT*, visceral tracheal trunk.

POSTSCRIPT, March 1st, 1915.

Ontogeny of the Gills in the Larvæ of Libellulidæ.

Since the above paper was written, I have succeeded in hatching a number of larvæ of *Diplacodes hæmatodes*, Burm., and have studied their gill-formation. Two females of this species were taken while ovipositing in the George's River, Ingleburn, N.S.W., on Feb. 13th last. Each laid a large number of eggs into a tube of water held in the hand. These eggs were placed with sand and débris in water in a Petri dish. In a few hours they became coagulated together into large masses. Within three days they developed a strong growth of fungus, so that I did not expect them to hatch.

However, on examining them nine days after they were laid, on Feb. 22nd, I found about two hundred newly-hatched larvæ in the dish. Some of these were quite transparent and freshly hatched. The gill-basket is very peculiar. It is of the *Simplex Undulate Type*, the main folds being clearly developed. Each main fold is brownish in colour and *very short*. On either side of it, *only one or two cross-folds* are developed. These are well supplied with tracheal capillaries, and are already recognizable as lamellæ by their size, shape, and inclination to the body-axis. No ecdyses having so far occurred, I cannot say definitely how the increase in the number of lamellæ takes place. From the position of the gill-basket, it seems likely that the first-formed lamellæ are the hindmost, and that others will be developed from behind forwards.

The above observation justifies the phylogenetic conclusions at which I had already arrived, that the Simplex Undulate Type is the most primitive type of Anisopterid rectal gill. At the same time, it marks off the Lamellate Type as very distinct in its origin, and apparently developed at an earlier period in the history of Odonata than were the other Duplex Types found in the *Æschninae*.—R. J. T.

Description of a new Species of *Idotea* (Isopoda) from the Sea of Marmora and the Black Sea. By WALTER E. COLLINGE, D.Sc., F.L.S., etc., Research Fellow of the University of St. Andrews (The Gatty Marine Laboratory, St. Andrews).

(PLATE 23.)

[Read 4th May, 1916.]

IN his interesting account of the Isopoda collected by the 'Thor' on the Danish Oceanographical Expedition, 1908-1910, to the Mediterranean and adjacent seas *, Stephensén records from numerous Stations *Idotea metallica*, Bosc, remarking: "The determination of this species proved at first a matter of some difficulty, owing to the fact that all the specimens—with the exception of those from Sts. 208 and 341, which had exactly the same outline as the figure given by Dollfus—were far narrower than they should be according to the statements and illustrations published."

For some time past I have felt convinced that there existed an allied species which was being confused with *I. metallica*. In connection with other work on this family of Isopoda, I have had occasion to examine large numbers of this latter species from our own coasts and from numerous localities abroad, and I have been struck by the general uniformity that prevailed in all the specimens. Thus it was practically impossible to find the slightest difference in shape, size, or colour, in examples from Japan, North America, the Mediterranean and Adriatic Seas, and our own coasts.

Miers † states that he had observed "considerable variation in the degree of prominence of the epimera [coxal plates] and in the width of the thoracic segments," and this only served to deepen the conviction that there existed two closely allied, but distinct species.

On comparing the figures of the appendages, etc., given by Stephensén (*op. cit.* p. 13) with some recently made of *I. metallica*, I noted numerous important differences, and so marked were these that I felt sure that he was dealing with a species quite distinct from *I. metallica*.

Dr. Stephensén has very kindly sent me for examination the whole of the specimens collected by the 'Thor' at various Stations, and upon examination it is at once evident that in addition to a few examples of *I. metallica*, Bosc, from Stations 208 and 341, the remainder of the specimens are quite distinct from that species. I am therefore describing the new species, with figures of the chief structural characters.

* Vol. ii. D. i. 1915, pp. 1-53, 33 figs.

† Journ. Linn. Soc., Zool. vol. xvi. (1881) p. 37.

It gives me much pleasure to associate the name of Dr. Stephensen with this interesting species, and to express my thanks to him and the authorities of the Zoological Museum of the University of Copenhagen, for their kindness in forwarding to me the whole of this interesting collection.

IDOTEA STEPHENSENI, n. sp. (Plate 23. figs. 1-12.)

Body oblong, with sides nearly parallel, slightly convex; surface finely rugose. Cephalon (Pl. 23. fig. 1) wider than long, anterior margin deeply excavate with the lateral portions produced as sharp points in front of the eyes; lateral margins sloping inwards, posteriorly with deeply impressed furrow. Eyes large and round, situated dorso-laterally. Antennulæ (Pl. 23. fig. 2) short, 1st joint expanded, articulating with the cephalon on the ventral side of the 1st joint. Antennæ (Pl. 23. figs. 3, 4) elongated and robust, nearly one-third the length of the body; peduncular joints robust, with short stiff setæ; flagellum with 11-12 joints and short style, excepting the first four all the joints are elongated. First maxillæ (Pl. 23. fig. 5) with outer lobe terminating in six stout curved spines and six finer inner ones, setaceous on the inner side; inner lobe with rounded head and three long setose spines, and a setule on the outer border of the distal end, setaceous on the inner side. Maxillipedes (Pl. 23. fig. 6) fairly long; palp 4-jointed, with the 4th joint produced anteriorly and indented on the outer margin; epipodite oval, distal inner lobe wide, basal plate short. The first four segments of the mesosome are almost subequal, also the last three; pleural plates of the 1st segment terminating in a blunt point, the anterior and posterior angles being cut away. Coxal plates (Pl. 23. fig. 7) occupying the whole of the lateral margins of segments 2-7, the posterior angles are drawn out as sharp points, which are directed laterally on segments 2-4 and posteriorly on segments 5-7. The appendages of the mesosome (Pl. 23. figs. 8, 9) slender and elongated, with bilateral and unilateral dentate spines on the sides (Pl. 23. fig. 10), also stout plain spines. Metasome (Pl. 23. fig. 11) with two short segments and strongly-marked lateral sutures indicating a third coalesced one, all laterally produced as sharp spines; terminal segment strongly arched, lateral margins converging very slightly towards the middle of their length, then expanded a little and curving to form two faint rounded lateral points and a median indication of a third one. Uropoda (Pl. 23. fig. 12) elongated, flattened, with nearly parallel sides, posterior margin slightly curved; endopodite almost straight on the inner margin, showing a blunt point on the inner side of the posterior margin, which is slightly emarginate, and with the outer margin cut away a little; setose style short.

Length of ♂ 31 mm., of ♀ 24.5 mm.

Colour (in alcohol) yellow, dorsally densely punctated with fine irregular blackish-brown coloured markings.

Hab. Sea of Marmora and Black Sea.

Type. In the Zoological Museum of the University of Copenhagen.

Remarks. To the naked eye *I. Stephenseni* is at once distinguishable from its ally, *I. metallica*, Bosc, by the prominent, somewhat triangular-shaped coxal plates of the mesosome and the form of the terminal segment of the metasome. Further, it is much more elongated than *I. metallica*, the sides of the body being nearly parallel.

I have carefully compared this species with specimens of *I. metallica* from Japan, North America, the Mediterranean and Adriatic Seas, and our own coasts, but all the 'Thor' specimens, excepting those from Stations 208 and 341, are very distinct from any of them.

In colour there is a marked contrast to the dull bluish green of *I. metallica*, for here the ground-colour is yellow, and, with the exception of the coxal plates, the whole of the dorsal surface is densely punctated with fine, irregular-shaped, blackish-brown coloured markings; these are also present on the antennulæ and antennæ, and the seven pairs of appendages of the mesosome.

I find very little, if any, difference in the general shape of the body in the two sexes, excepting that the females are rather smaller—a feature, in a somewhat lesser degree, common to *I. metallica* also.

The cephalon is wide with the anterior margin curving deeply inwards, whilst laterally it is produced in front of the eyes, the two processes terminating in sharp points. Stephensen's figure does not show these in sufficient detail.

The antennulæ are short with the 1st joint expanded. The point of articulation with the cephalon is on the ventral side of this joint, and not at the base as in *I. metallica* and most other members of the genus.

The antennæ are elongated—in specimens 29.5 mm. long, they measure 12 mm. in length. The setæ on the joints of the peduncle are very characteristic, and quite distinct from anything I can find in *I. metallica*. The 1st joint is small, the 2nd and 3rd almost subequal, the 4th longer, and the 5th the longest of all. The first four joints of the flagellum are ill-defined and short, the remainder being elongated; all have short setæ at the distal end of each joint.

The first maxillæ are stouter than in *I. metallica*, terminating in twelve spines on the outer lobe, and three long setose ones and a setule on the inner lobe.

The maxillipedes are much longer than in *I. metallica*, and the 4th joint of the palp is produced anteriorly, whilst the outer margin has a series of five or six indentations. The groove on the 3rd joint is fairly conspicuous, as

also the thickening of the outer rim of the 4th. The distal inner lobe is widely expanded, and the basal joint short.

The first four segments of the mesosome are almost subequal, and a little longer than the last three. The pleural plates of the 1st segment are directed laterally, and terminate in a blunt point, whereas in *I. metallica* they are slightly expanded, with the anterior and posterior angles rounded. The coxal plates in *I. metallica* occupy the whole of the lateral margins of the 2nd-7th segments, with the posterior angles of the 5th, 6th, and 7th only produced backwards. In *I. Stephenseni* they all stand out from the pleuron as more or less triangular plates, attaining their greatest dimensions on the 4th segment. The terminal portion of the pleuron in each mesosomatic segment is also different from the condition seen in *I. metallica*, being rounded in front and drawn out as a short sharp point posteriorly. On the 5th-7th in the middle of the lateral border of the pleuron there is a slight indentation.

The appendages of the mesosome are much more slender than in *I. metallica*, with the last joint much longer and less robust. These are well shown in the five figures given by Stephensen *. On the sides of the joints there are numerous dentate setæ, some with double rows of teeth, and others with teeth on one side only, in addition to numerous plain spines of various lengths.

The metasomatic segments afford a striking contrast to the condition obtaining in *I. metallica*, where the first two have their pleural plates laterally rounded, also those of the imperfect third segment, while the long terminal segment usually has a more or less strong median ridge, and the lateral margins gradually converging to a truncate posterior extremity. In all the specimens I have examined this posterior margin is sharply truncate, there being no sign of emargination or lateral extensions. In *I. Stephenseni* the pleural plates of the segments 1 and 2 and the imperfect 3rd are laterally sharply drawn out, whilst the terminal segment has the lateral margins very slightly curved inwards about its middle, with the posterior margin terminating in two small, lateral, rounded points, with a slight indentation beyond each and a faintly produced median process. These characters are present in all the specimens examined ranging from 6 mm. to 31 mm. in length.

The figure of the uropod given by Stephensen (*op. cit.* p. 13, fig. 4, *Up.*) is of *I. metallica*, and not of this species.

I. Stephenseni is undoubtedly closely allied to *I. metallica*, Bosc, but perfectly distinct from it, both males and females being easily recognized from the very young stages onwards.

* Danish Oceanographical Expedition, 1908-10, vol. ii. D. i. 1915, pp. 1-53.

EXPLANATION OF PLATE 23.

Idotea Stephenseni, n. sp.

- Fig. 1. Dorsal view of the cephalon. $\times 5$.
2. Dorsal side of the left antennule. $\times 16$.
3. Dorsal side of the left antenna. $\times 9.5$.
4. Terminal style of the antenna. $\times 80$.
5. Ventral side of the terminal portions of the inner and outer lobes of the right 1st maxilla. $\times 45$.
6. Ventral side of the right maxillipede. $\times 22$.
7. Dorsal view of the lateral portions of the mesosomatic segments, showing the coxal plates. $\times 4$.
8. Ventral view of the 2nd thoracic appendage. $\times 12$.
9. Ventral view of the 8th thoracic appendage. $\times 12$.
10. Bidentate seta from the 8th thoracic appendage. $\times 160$.
11. Dorsal view of the metasome. $\times 3$.
12. Left uropod. $\times 5$.

All the figures are drawn from a male specimen.



H.G.K. del.

Cambridge University Press.

IDOTEA STEPHENSENI, n.sp.

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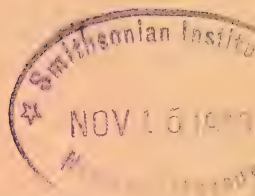
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VOL. XXXIII.

ZOOLOGY.

No. 224.

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Experiments and Observations bearing on the Explanation of Form and Colouring, 1908-1913. By C. F. M. SWYNNERTON, F.L.S.

[Read 15th April, 1915.]

1. GENERAL INTRODUCTION.

A. WORK TO BE DESCRIBED.

WHEN I was in England in 1908 my old friend Mr. G. A. K. Marshall, who, since he first guided my ardour for Natural History into useful channels in the Natal Coast Bush and at Salisbury in 1897, has never ceased to help and encourage me in every possible way, strongly urged me to carry out on my return to Chirinda a series of experiments designed to test the validity of the current theories of mimicry. He suggested the following programme:—

“1. The testing of every available butterfly (and where possible its larva and pupa) on every available bird, and a rough classification of the insects into grades of palatability for every animal used.

“2. The testing by a special series of experiments of Müller’s assumption that the experimental destruction would be the same for every type of warning coloration.

“3. A careful account of the habits and flight of all distasteful species and their mimics.

“4. The releasing of damaged butterflies to wild birds.

“5. Tests whether birds are deceived by resemblances in their prey.”

Professor Poulton, in a letter dated May 26th, 1909, wrote :—“I am most anxious to know about the edibility of the forms that, in my opinion, probably belong to a second category of distastefulness—long behind the *Danaines* and *Acræas*, but still, I believe, distasteful . . . any forms that have fairly conspicuous undersides.”

A little later he and Mr. Marshall independently suggested to me that I should make a special point of investigating the defences of the larger species of *Charaxes*.

I would like to say at once that not only am I indebted to these two friends for the inspiration to much work that I have found most fascinating and absorbing, but that both have continued to be lavish of help and encouragement and most generous in their gifts to me of their own and other publications on the subject. I can say without exaggeration that any value that work may possess is primarily due to them. And they have gone to immense trouble over the identification of my insects. Also, I have to leave for Africa before this paper goes to press and Professor Poulton, with the utmost kindness,

has offered to see it through for me—a very laborious task, I fear. Dr. Rendle, Mr. S. Moore, Mr. E. G. Baker, Mr. G. A. Boulenger, Mr. Oldfield Thomas, and Mr. Dollman have all kindly helped me with identifications and often suggestions, and Mr. H. Eltringham with much useful suggestion and advice. Mr. David Odendaal and his young brother Thompson Odendaal helped very much in Africa in the collection of material, particularly for my experiments on carnivorous animals. I am indebted to Mr. H. C. Bryant, Dr. F. A. Dixey, Prof. Newstead, Mr. S. A. Neave, and Mr. J. C. F. Fryer for copies of their papers, a form of help that I have found very useful. My kind friend, the late Miss H. J. Robins, in the midst of exacting work of her own, insisted on devoting her already too scanty spare time to “helping on the cause of science,” as she put it, in typing for me a considerable portion of the present paper. And last, but not least, I wish to acknowledge my debt to my wife. Her help, which, apart from encouragement, has taken the form of the papering of some thousands of insects and the laborious copying out of much of my very illegible manuscript, has been invaluable.

Interesting suggestions arising out of my results tempted me in July, 1911, to add very greatly to the original programme. A first attempt to work out and piece together my general experimental results to that date had not only shown me that that original programme was now nearly sufficiently completed, but, in conjunction with certain of my observational results, had strongly suggested considerations which, it seemed to me, would, if generally applicable, aid in accounting for some rather difficult facts in animal coloration—including many to which “sexual selection” had been somewhat unsuccessfully applied.

So other animals were now to be used besides birds, other prey besides insects, the main subject of enquiry was no longer to be mimicry, and such further points as the validity of sexual selection were to be tested with some degree of thoroughness. The net result, had I carried out my new programme as fully as I intended, would have been the postponement of publication for very many years more. However, both Professor Poulton and Mr. Marshall, to whom I sent a first account of my results, new ideas, and further plans in February of 1912, strongly, and I think rightly, urged me at least to commence publishing my detailed experiments soon, while reserving any full discussion of my main conclusions until I should have satisfied myself, by means of this further work, of their probability. Hence—after a delay caused by the execution of my extended programme on a smaller scale than I had intended—this paper.

My intended order of publication is as follows :—

1. Experiments on wild birds, devised mainly to ascertain :
 - (a) Whether or no they readily prey on butterflies ;
 - (b) Some of their preferences,

Here I include also experiments on unconfined Ground-Hornbills and, for comparison of its tastes with those of wild individuals of the same species, my experiments on a captive Bee-eater.

2. As a standard for comparison, my perhaps most complete series of preference experiments—that on my captive Rollers.

3. Experiments on insect-eaters other than birds, experiments on carnivorous and other animals, including my experiments in connection with plants.

In this introduction I will deal with the objections which, to my knowledge, have been brought against the experimental method. There will remain the objections to a selectionist view—as “Hypertely,” “valuelessness of incipient resemblance,” “instinctive knowledge of food-values,” “night-hunting of the larger Carnivora,” and so on. I have special work bearing on all of them and I hope to describe it in detail in some future publication, but I will meanwhile state its bearing, quite briefly, in giving my conclusions at the end of the third section. This third section does, I think, suggest that the conclusions we may draw from our results on insects are probably capable of a very extended application. It will be followed by a brief preliminary statement of the bearing of the general results on the theories of animal coloration.

There will still remain for later and separate publication :

4. The remaining experiments on captive insectivorous animals and on eaters of birds' eggs and insects' eggs.

5. Such observations, fairly extensive, as have been made on the habits and usual backgrounds of the various species of prey used in the experiments ; and some account of the habits, relatively to them, of their enemies. Final conclusions from the whole of the work.

Captive insectivorous animals experimented on.

My best series of preference experiments in insects have been on four species of birds—on *Lanius collaris*, Linn., and *Dicrurus afer*, Licht., amongst Passerines, and on *Halcyon cyanoleucus*, Vieill., and *Coracias garrulus*, Linn., in the Picariæ.

Other useful series of experiments, “preference” or otherwise, have been on a monkey (*Cercopithecus albogularis beirensis*, Poc.) ; on four Passerine birds (*Emberiza major orientalis*, Shelley, *Phyllastrephus milanensis*, Shelley, *Pycnonotus layardi*, Gurney, and *Crateropus kirki*, Sharpe), two Picarians (*Lophoceros melanoleucus*, Licht., and *Merops apiaster*, Linn.), an Owl (*Syrnium woodfordi*, Smith), two Falconidæ (*Aquila wahlbergi*, Sundev., and *Asturina monogrammica*, Temm.), and a Francolin (*Francolinus shelleyi*, Grant) ; on a lizard (*Mabuia striata*) and a chameleon ; and on a few Arthropods, notably a Solpugid (*Solpuga sagittaria*, Poc.), a Locustid (*Enyalipsis petersi*,

Schaum), a Tenebrionid beetle, a dragon-fly (*Anax speratus*, Hagen), and Asilidæ (mainly *Alcinus rubiginosus*, Gerst.).

A very large number of experiments were carried out on European and Lesser Stripe-breasted Swallows (*Hirundo rustica*, Linn., and *H. puella*, Temm.), but the *preference* results were hardly in proportion to the time and labour expended, as it was before I had learned to experiment effectively. Other insect experiments that were to some extent wasted for the same cause, or else were very scanty, were on *Cercopithecus pygerythrus*, F. Cuv., *Papio cynocephalus*, Geoff., *Crossarchus fasciatus*, Desm., *Petrodromus tetradactylus*, Pet., *Dendromys* spp., *Hyphantornis jamesoni*, Sharpe, *Coliopasser ardens*, Bodd., *Lanius collurio*, Linn., *Telephonus senegalus*, Linn., *Phyllastrephus flavistriatus*, Sharpe, *Apalis thoracicus*, Shaw & Nodder, *Irrisor erythrorhynchus*, Lath., *Centropus burchelli*, Swains., *Lophoceros leucomelas*, Licht., *Chrysococcyx cupreus*, Bodd., *Bubo maculosus*, Vieill., *Francolinus coqui*, Smith, *Pternistes humboldti*, Peters, *Numida mitrata*, Pall., *Lobivanellus lateralis*, Smith, a toad, a lizard (*Agama* sp.), Mantidæ, *Harpactor erythrocnema*, and one or two other Reduviidæ.

Unconfined predaceous arthropods tested to some slight extent have been spiders and driver-ants (*Dorylus* sp.). A list of the unconfined birds will be given later. The main experiments here have been on Bee-eaters (*Merops apiaster*, Linn.), a Bush-Shrike (*Dryoscopus guttatus*, Hartl.), a Robin (*Tarsiger stellatus*, Vieill.), a Drongo (*Dicrurus ludwigi*, Smith)—all of these actually wild; also tame but unconfined Ground-Hornbills (*Bucorax cafer*, Boc.). But attacks, in some cases numerous, were watched in the case of thirty-five species of unconfined birds in all. I have some other evidence bearing on the question "Do Birds eat Butterflies?" besides that contained in Section 1 of this paper, and I will postpone any really full discussion of the point until I shall have published it.

Some attempt has been made to carry out the experiments generally on a sufficiently large scale. They number at the moment of writing about 1600 in all, including the 120 experiments and special observations on wild birds that are for the most part comprised in Section 1. I believe that approximately 20,000 insects (not including the very numerous small grasshoppers that were so often given simply to alter the state of an animal's appetite) have been used in all in the course of the experiments, and of these all but two or three thousand were butterflies. And some were offered many times over. Here I would like to say, in view of some recent criticism (Proc. Ac. Nat. Sci. Philad. 1912, pp. 281-364), that Professor Poulton was from the start foremost in urging on me the necessity for testing the question of preferences on no small scale but with *masses* of material, not with one or two offerings of each species but with *many*.

I comment later on the carnivorous and other animals used. Some of the results were very interesting. I was much disappointed at not securing a

lion or a leopard for my trials of the larger mammals, particularly of man, my experiments with the flesh of whom were prompted by Darwin's admitted difficulty in accounting for the smells of the different races and certain other distinctive characteristics in man generally. I trapped for months, as did very kindly my nearest neighbour, Mr. W. N. Odendaal. On one occasion a leopard was actually caught, but had, when discovered, already found a weak spot in the trap and was in the act of breaking out, so had to be shot. I intend to try again. The Herbivora used were domestic, and I had not time before leaving Africa to complete the experiments. They are sufficient for my present preliminary purpose.

It will be noticed, finally, that though the experiments included in this paper and those yet to be published are mostly and primarily preference experiments, many defences other than "nauseousness" have been tested, and, in special connection with Mimicry, there have been numerous trials as to whether animals are deceived by resemblances in their prey. Of the insects thus used the following species have been beautifully figured by my gifted friend Mr. H. Eltringham in his fine and useful book on 'African Mimetic Butterflies': *Danaida chrysippus*, L., with its forms *alcippus*, Cr., and *dorippus*, Klug; *Hypolimnas misippus*, L., with its corresponding forms *alcippoides*, Butl., and *inaria*, Cram.; *Argynnis hyperbius*, L.; *Acræa encedon*, L., and *Mimacræa marshalli*, Trim.; *Papilio leonidas*, F., and *P. leonidas* f. *brasidas*, Feld.; *Amauris ochlea*, Boisd., *Pseudacræa lucretia* f. *expansa*, Butl., and *Hypolimnas deceptor*, Trim.; *Amauris niavius dominicanus*, Trim., and *Hypolimnas dubius* f. *wahlbergi*, Wllg.; *Amauris albimaculata*, Butl.; and *Hypolimnas dubius* f. *mima*, Trim.; *Acræa zetes acara*, Hew., and *Pseudacræa boisduvali trimeni*, Butl. (figs. 9 and 10 of Plate 6 are most like the individuals used in my mimicry experiments); *Atella phalantha*, Drury, *Mylothris agathina*, Cram., *Belenois thysa*, Hopff., and *Eronia argia*, Fabr., *Pardopsis punctatissima*, Boisd., and *Pentila amenaïda*, Hew.; *Terias brigitta*, Cram., and *Terias senegalensis*, Boisd.; *Nychitona medusa*, Cram.; and *Papilio dardanus* with its various mimetic females.

But carnivorous and egg-eating animals were also somewhat strikingly deceived by resemblances in their prey, and I have seen Herbivora obviously deceived too—despite their sense of smell, which is not always used where visual evidence seems convincing.

The publication of the details of my experiments has been thought to be perhaps unnecessary by one or two of my friends. To them I must still reply, and I am glad to find that Professor Poulton fully agrees with me, that the whole object of the investigation was to obtain that mass of actual evidence for or against the selectionist views of animal coloration that has so far been lacking, and which the opponents of those views have insistently, and very rightly, demanded: that the mere statement of the experimenter's conclusions is no evidence—only the detailed experiment, to be examined critically and

made to yield other conclusions if the experimenter is found to have been misled through bias or error or ignorance, is evidence; and that it is only right to place this evidence on record and at the disposal of all who may at any time care to study it and draw those other conclusions if they can. Even the giving of sample experiments is no guarantee against erroneous deduction in those that are not given.

To give only one example of the very great danger attaching to incomplete publication in a matter of this kind, I may say that, with increased knowledge, I myself now draw quite different conclusions from my own first five hundred experiments from those I drew at the time. Yet five hundred is a large number, capable of forming a paper nearly as long as the whole of the present one, and had I at that time decided to publish them in full my decision would almost certainly have met with the friendly criticism it has met with to-day. The result, had I contented myself with the publication of my conclusions, would have been utterly to mislead. So now, I can be by no means sure that I have extracted all conclusions of importance that can be extracted from my experiments—I know that I have not—or that the discovery of some new complicating factor still unknown to me may not yet invalidate some part of my present conclusions. This, as I shall relate, actually happened to me not very long ago. I feel, therefore, that the only safe course is to place on record the exact details *of what the animals actually did*.

B. ARE THE EXPERIMENTAL RESULTS PROBABLY TO BE RELIED ON? *

The reader may object (very reasonably) that records of wild birds actually attacking butterflies are even now all too scarce; that tens of thousands of their stomachs have been examined, in almost every case with negative results; that where wild birds *have* been seen to eat butterflies these have very frequently indeed belonged to so-called nauseous species and that destruction by birds cannot therefore fairly be regarded as discriminative. Finally, even admitting that discrimination may take place, what proof is there that a captive bird's preferences will fairly represent those of a bird in the wild state? If a pet and in the habit of receiving dainties from its owner, may it not tend to eat on trust even unpleasant insects? With appetite and digestion impaired by fear or fretting or if stinted of its natural range of food, is it likely to be a suitable subject for this kind of experiment at all? Captive birds have eaten what they are not known to eat in the wild state and refused prey that in the wild state they have been found to eat. "Unless, therefore," the reader might conclude, "you can first satisfactorily meet these very real

* This, and the introduction generally, was originally written in relation to the experiments with insects. *Mutatis mutandis*, a great deal of it is applicable to the experiments in which vertebrates and plants were used. A good case can be stated, I think, for the reliability of these too.

objections, you can hardly claim that any results you may have obtained from, at any rate, captive animals are necessarily in the least degree reliable." I would agree ; and it is only because I believe that these objections can be amply met in the way required by my critic that I have, as a matter of convenience, adopted the present order. I think it right, however, in the meantime to indicate the lines on which I would be prepared to meet the criticisms :—

1. *Apparent reluctance of birds to feed on butterflies.* [The following was written long before my recent short paper for the Entomological Society (Proc. 1915, p. xxxii), and should be read in conjunction with it, also with my paper on the subject in 'The Ibis' (Oct. 1912, p. 635), with Mr. Marshall's paper referred to below, and my own remarks at the end of Section 2 of the present paper.] I cannot help feeling that those who have believed that birds do not feed to a very appreciable extent on butterflies have, at any rate, had a good deal of apparent justification for their opinion. The evidence supporting that opinion is of a negative character, but it is bulky. As for its quality, I should suppose that some at least of the very extensive and admirable American stomach investigations that failed to reveal much in the way of butterfly *débris* were microscopical : I do not know how completely exhaustive in relation to the very finest *débris* they were, or to what extent specially directed towards the finding of Lepidopterous remains. So far as actual attacks seen and recorded are concerned, Mr. Marshall's painstaking and highly resultful investigation showed (Trans. Ent. Soc. Lond. 1909, pp. 329–383) that these have been vastly more numerous than was generally believed : his total was close on six hundred, and very many of the records were multiple. At the same time, butterflies being as a whole the most conspicuous and distinctive of insects, and attacks by birds on less recognizable insects being a matter of such daily observation (I speak, at any rate, of my own experience), it would certainly seem significant that attacks on butterflies too are not witnessed with the greatest frequency. Mr. Marshall has suggested one or two excellent and cogent probable reasons for this lack of evidence, and I am able, from my own observations, both to confirm these and to add one or two others.

Butterflies are, in any case at Chirinda and in many other parts of the world, by no means abundant relatively to the members of certain other orders. At a time when butterflies were particularly abundant I have watched more small Diptera, etc., cross a shadow in half a minute than I have seen butterflies in the whole day ; each year I have watched the great grass-fires drive out the butterflies as single spies, but the grasshoppers in battalions ; I have roughly calculated that probably more driver-ants passed a certain spot in one hour, and that more wild hive-bees could be seen any day in April at a single one of my *Eucalyptus saligna* gum-trees in a very few hours, than the number of butterflies ever seen by me in a year—this

though I have collected largely at the fruits and flowers that bring butterflies together as the *Eucalyptus saligna* flowers bring the bees.

Therefore, considered absolutely, attacks on butterflies, whenever and wherever they are thus outnumbered, are unlikely to be as numerous as those on the insects that outnumber them. Even relatively, however, butterflies are likely to suffer somewhat less than more abundant insects—that is, if my own observations and those of, I believe, at least one American observer (Mr. H. C. Bryant), to the effect that birds tend to concentrate their attention somewhat specially on what (of an acceptable nature) is at the time most readily obtainable in quantity, be correct.

These factors, with certain others not worth going into again here as I have dealt with them so recently, probably account for the otherwise puzzling fact that we do actually see fewer attacks on butterflies than on insects of certain other orders. But, at Chirinda—and I have at present no reason to suppose that the locality may be exceptional in this respect—I have obtained evidence that even if they should enjoy a certain amount of relative immunity under the circumstances I have suggested, butterflies are probably nevertheless *very greatly* persecuted, even at times by those birds that specialize primarily in other directions; and I find it interesting to contrast my results obtained during two different periods.

In eleven years, during which I paid no very special attention to the subject, I witnessed only about twenty attacks by wild birds on butterflies. In four years, during small portions of which I *did* pay special attention to it, I obtained records of over 800 such attacks. Nearly all these were witnessed by myself, the majority of them within a single month, during which I made a point of working at the subject amongst the wild birds of the forest outskirts for an hour or two each day. The method was mainly (not solely) experimental, but in many of my experiments thoroughly vigorous, unmaimed and strongly-flying butterflies were freely used, and even these drew numerous attacks. Again, during the first period mentioned, I examined, non-microscopically, more than 1000 stomachs of insectivorous birds, and in only five found butterfly remains. I later found, by the close examination of pellets the raw material of which was known to me, that butterflies, including their wings, tend to be broken up so finely in a bird's stomach that their presence is often only to be recognized by the use of a lens that will readily show the scales, etc., and their absence only to be established as the result of a completely exhaustive examination of the whole of the finest *débris*, which in some cases may take very many hours. This led me to a decision to re-examine the stomach-contents I had collected, and although up to the present, through lack of time, my re-examination has not proceeded far, the initial indications are that the proportion of stomachs with Lepidopterous remains will be higher than at first. Other lines of investigation (testing of newly captive and wild birds for previous knowledge, examination of excreta picked up at random

in the forest, etc.) have all produced results pointing in the same direction. It is perhaps yet more important, for it is this that best enables us to judge of the *extent* of such persecution as is suffered by butterflies, that I have obtained good direct evidence in favour of the view that it is birds that probably chiefly inflict the wounds that are present sometimes in the wings of nearly every fairly high-grade butterfly one sees.

2. *Discrepancies between the attitude of wild and tame individuals of the same species towards the same food.* In animals (and especially, amongst birds, in hand-reared nestlings) that have become accustomed to a particular kind of food I have often noticed the growth of a kind of conservatism that makes them reluctant after a time to try new foods, even foods that are eaten freely by other individuals, wild or captive, of the same species—and I shall describe, when I come to it, a particularly good contrast of this kind that occurred between two of my captive bulbuls.

I shall also have much to say, even in this introduction, of exactly the opposite phenomenon—namely, the tendency of animals accustomed to a wide range of food to develop special eagerness for food of which they are largely deprived and relative indifference or even repugnance to the foods they chiefly receive.

These two principles I have seen illustrated at different times even in a single individual (a lemur, *Galago crassicaudatus*) and, with that to be described in the next paragraph, they have seemed to me to be largely capable of accounting for, at any rate, such cases of apparent discrepancy as I have myself come across.

3. *Apparent indiscriminateness of wild birds.* My experiments on wild birds (at any rate) show that it does not require, necessarily, literal starvation to make a bird eat *Danainæ* and *Acræinæ*: a mere empty stomach (in some birds rather less)—combined with a good hungry appetite—may suffice. When it has eaten a little food it will refuse insects of this very low grade, but accept others which will in turn be refused with growing repletion, though insects that are a little pleasanter will continue to be taken: and so on, through several grades, up to actual repletion-point, near which only the very “pleasantest” insects of all will be accepted. This is a statement which my experiments will be found to support in the most ample manner, and the fact stated will probably in most cases account for the frequent eating of low-grade insects by wild birds; for the refusal sometimes by captive birds of food that the species is known to eat in the wild state and *vice versa*; and for much that might be regarded as inconsistency on the part of captive animals. I could give many instances of the working of the principle, but the following must suffice:—

(a) *Flocks of wild bee-eaters (Merops apiaster) may daily be seen eating immense numbers of hive-bees, and I have taken as many as 23 from a single*

stomach; yet a captive bee-eater refused to touch them, emphatically and repeatedly, though she readily accepted and ate certain other insects.

This observation by itself would be most puzzling, and might well help to discredit utterly experimentation on captive birds—as might any one of various other observations of exactly the same kind that I have in mind. Yet my bee-eater only thus refused bees when a certain point in the satisfaction of her appetite had been reached. Up to that point I found that she ate them readily, and careful and repeated observations on numerous wild bee-eaters of the same species (*Merops apiaster*) showed that they too apparently only ate hive-bees up to a certain point, thereafter ignoring all they were seen to meet, but attacking and eating various other species of insects.

(b) I have myself accused rollers of being, probably, indiscriminate feeders on the strength of such strongly-smelling insects as the grasshopper, *Phymateus*, having been found in their stomachs and because a roller in my aviary (*Coracias olivaceiceps*) accepted and ate them on several occasions with apparently the greatest relish.

I had no knowledge of the state of repletion of the latter roller, nor could I possibly know the exact state of hunger or otherwise of the wild roller whose stomach was examined, at the moment each ate his *Phymateus*. And I now realize that, without that knowledge, I was utterly and completely unjustified in coming to any conclusion at all, either as to the insect being highly pleasant or the roller indiscriminate. Offered to *C. garrulus* (B), the *Phymateus* was eaten, it is true, but only up to a certain point in the satisfaction of the bird's hunger, and not beyond it. The finding of a particular insect in the stomach of a wild bird, even frequently and in large quantities (as in the bee-eater instance just given), at most proves that that species of bird will eat it when hungry enough. It in no way invalidates such conclusions as may be suggested by the rejection of the same insect by the same species of bird, captive or otherwise, when it is *not* hungry enough for it, yet is hungry enough for certain other species of insects. It can be seen, too, from what I have said, how futile any attempt must be to deduce the status of, say, the *Acræinæ* used in any series of experiments by merely counting up their total rejections against their total acceptances. If they were offered mainly to hungry birds the acceptances probably would be more numerous than the rejections, but this would not indicate that the *Acræinæ* are as digestible as things eaten to nearer repletion-point, or that they would ever be eaten at all under conditions other than those under which they were offered—a nearly empty stomach and a rousing appetite.

Stomach and pellet investigation must, I think, remain our greatest and most valuable source of information with regard to the *general* preferences of a species, the orders it usually feeds on, and the insects it mostly “fills up” on, as a bee-eater does on bees. But facts like the above seem to indicate that our knowledge of its detailed preferences must come in the main from

continuous observation of individual unconfined birds and from special experiments both on wild birds and on captives*.

Experiments on wild birds are obviously quite indispensable, if only as a check on the others, but on captive birds they can be carried out in far greater numbers, with greater ease and precision, and with fewer insects than are required for wild-bird experiments, so that it certainly seems well worth enquiring whether, conducted with care on suitable birds, suitably fed and looked after, they need really be so very unreliable. The factors, apart from lack of exercise and limited choice of food (with both of which I will deal later), that would render them unreliable, seem likely to be:—Fretting, ill-health, fear, suspicion or (the opposite) over-confidence.

An animal that mopes, whether from ill-health or rebellion at confinement, and continues to mope, is useless for experiment of this kind—and often unusable. As might be expected—for even with ourselves ease of mind is a condition of good digestion,—its appetite is lacking or so capricious that it is frequently quite impossible to assign a value to its acceptances or refusals. The variation in individual animals, even of the same species, is sometimes great. Thus of two kingfishers (both *Halcyon cyanoleucus*), one at once took most kindly to captivity, showing no appreciable fear of me when I approached his cage, and, on my offering him various insects with the forceps little more than an hour after his capture, accepted and ate them most readily. The other (captured at a later date) fluttered to get out, and when it finally gave this up, simply pined away, refusing food or accepting it only in small quantities and capriciously. I have had similar experiences with a few other birds, with a lizard (*Agama* sp.), and with a toad. Needless to say, I claim no reliability whatsoever for the “results” obtained from these animals.

The restlessness that is sometimes present for a few days after capture (or—at any rate, if not confined to the night-time—that which appears at migration-time) is also a form of unsettlement that is inconducive to consecutive and therefore reliable experimentation. Fear of the experimenter falls into the same category so far as its result is concerned, but its continuance for more than the first few days will in many cases (if I am safe in judging from my own experience) probably be the fault of the experimenter. I have found that the persistent quiet offering of pleasant insects through the bars by the forceps to newly-captured birds has in all but very intractable cases sooner or later evoked a response. This is usually at first a timid one, but, once it has been obtained, a little more persistence on my part has almost invariably soon begun to win the bird’s confidence. Delay in obtaining this has usually been simply the result of my being unable to devote the necessary time to the bird.

* These and certain other opinions offered in this introduction I hope to state in greater detail and with such qualifications as may be necessary at a future date.

Suspicion of the food offered is another condition during the continuance of which any results that may be obtained must be duly discounted. Again, judging simply from my own experience, it is likely, I believe, to be due usually to lack of tact on the part of the experimenter. Thus the offering of a number of highly unacceptable insects without a good admixture of more acceptable species to a bird that is just learning to take from the forceps would be a mistake. My baboon afforded an extreme instance of this suspicion, the result, apparently, of my having offered him unacceptable insects hidden in balls of dough, and I have noticed that trickery in any form—such as disguise by the attachment of another insect's wing—tends, where detected, to produce temporarily a suspicious frame of mind in previously confident birds. Usually I have found such suspicion to be quite transient. It is also, as a rule, readily recognizable and can be allowed for.

Over-confidence is likely only to take place in an over-petted animal that is continually being offered dainties by hand, and even in it only during the first experiment or two in which any number of unpleasant insects are used. It is, in any case, unlikely to be present in a bird that has already had ample experience of unpleasant insects in the wild state.

To sum up on these few points :—Fretting, ill-health, restlessness, fear of the experimenter, suspicion of the food offered or over-confidence, are each and all perfectly capable of vitiating the results of any experiment throughout which they are present. This certainly constitutes an exceedingly strong plea for care in the treatment and selection of the animals to be experimented on, but I am not at all sure that it is any more a valid argument against "captive" experimentation generally than the fact that some charities are undeserving of attention is an argument for refusing to contribute to charities at all.

Some individual animals are refractory under confinement, or otherwise unsuitable for experiment. These should not be used (or, if they *have* been used, should not be regarded as necessarily reliable). Others, even though captured when adult, take confinement very placidly, soon become thoroughly friendly with the experimenter, feed well, and keep in excellent health and condition. Birds of this stamp seem to me likely to be useful subjects for experiment in captivity—always subject to the difficulties, yet to be discussed, connected with food and exercise. Amongst others of this kind were my chief European roller (B), my kingfisher, my shrike (*L. collaris*), and my drongos.

4. *The food difficulty.* I have from the very first realized the importance of this and have made it a point that the food should be abundant, varied, and so far as possible natural. One special native always (occasionally two)—chiefly when Diptera or hive-bees were wanted in special quantity, as for the swallows, drongos, and bee-eaters—has done nothing else all his time but catch various insects for the birds. This quite apart from any native (or

myself) who might be collecting butterflies, etc., for the actual experiments. The following statement will, I think, show that for the few birds to which I confined myself at any one time it was possible, even with this small amount of assistance, to do a good deal in the way of variety.

Our commoner Orthoptera—Locustids, Acridians, Crickets, Mantises, etc., in great variety—have usually formed the daily *pièce de résistance* for such birds as cared for them (that is to say nearly all), while portions of termite-nests containing commonly, in addition to the ordinary workers, which were not liked, females and larvæ, which were more readily eaten, were placed daily, broken up, in the trays, the latter having been first filled each morning with leaf-mould and rotten wood. This was brought straight from the forest close by, and often contained much small insect-life of a kind that would have been difficult to obtain otherwise. It had to be discontinued in wet weather owing to its making the cages too damp. These foods were constantly supplemented by such other abundant insects as happened to be in season, as cockroaches, migratory locusts, both larval and winged, an Asilid fly (*Alcimus rubiginosus*) that is abundant during the spring and summer, house-flies and other Diptera, as also hive-bees, rewards being given to natives bringing me the latter insects in any quantity during my time of greatest experimentation with bee-eaters and drongos, the abundant and gregarious ant-lion imago, *Formicaleo leucospilus*, dragon-flies (*Orthetrum* spp.) when plentiful, winged termites, *Sphingomorpha chlorea*, *Nyctipao macrops*, *Cyligramma latona* and other common Noctuidæ—and so on. Of the moths, the *Sphingomorpha* has been sometimes so abundant on the banana-branches hanging in the verandah and on fallen guavas or other fruit as to enable a one-pound tea tin to be filled with them evening after evening in the space of perhaps half an hour.

Of butterflies, *Charaxes brutus* and *C. candiope* have also sometimes been so abundant as to enable me to feed them to some extent to the birds, and it will be seen that during a portion of the time when I was experimenting on swallows, I was able to give them *Pyrameis cardui* in such numbers that it proved quite a large item in their daily food. Coleopterous food in the adult state—that is, of species that the bird would have eaten—would have been difficult to obtain in any great variety without the employment of much additional labour, but *Neptunides polychrous* and other Cetoniidæ were collected during their seasons of abundance, killed and thrown in to the larger birds, *Anomala* and the other Rutelid beetles that are such a pest to our gardens were supplied in numbers, and such larvæ, mainly Coprids, as were dug up in the garden or could be obtained from manure-heaps were also given.

The Coprid larvæ were disliked, but a few might be eaten if placed in the cages (as they usually were) before other food had been supplied. The larvæ and pupæ of the Cetoniid beetle, *Rhabdotis gulica*, on the other hand, were far

better relished by all and were eaten in considerable quantities, being obtainable in abundance from the sheep-sheds. Special consideration in the matter of variety was given to those birds that were being chiefly experimented on at the time, and sometimes numbers of spiders and insects in great variety, including numerous Diptera, would be obtained by "sweeping" and thrown in to them.

The known tastes of the birds were always, so far as possible, consulted: thus the swallows had a special boy of their own whose one business it was to catch Diptera. The Barratt's bulbul (*Pycnonotus flavistriatus*) was specially supplied with wood-lice and such other subcortical species, spiders, etc., as I could obtain for it in the forest (its habitat), also with the fruits of *Celtis dioica*, S. Moore, a fruit I have frequently taken from the stomachs of wild individuals of the species. The other bulbuls received bananas, papaws, guavas, oranges, and occasionally other fruits in addition to their insect-food, and occasional meat-eaters, as the roller and shrikes, sometimes received a dole of meat or a lizard, a mouse or a bit of snake.

The owl received chiefly meat, but also insects, especially during periods of experiment, and the buzzard-eagles both meat and insects, especially quantities of migratory locusts which were abundant in their time. Naturally during long periods of no experimentation my efforts in the direction of variety were also relaxed—extra help was discarded, rewards were not offered, sweeping and all other special methods were dropped: yet even then the bird-boy, whose sole daily work it was to clean the cages, provide ample water, and catch insects for the birds' food, used to bring in the latter at such times mainly (but by no means entirely) Orthoptera, in great variety. I have on one or two occasions (I will mention them in describing my experiments) had to recommence experimenting on a bird that had for some time previously been receiving its food in this rather more limited variety. I have, I think, noticed no departure at such times from its usual preferences *provided it was suitably fed during the few hours preceding the experiment*.

The precaution italicized is at times an exceedingly necessary one. I have known a guinea-fowl tired of grain and a bulbul tired at one time of fruit, at another of insects. My drongo (since I ceased experimenting on him regularly) has shown "vitiatio" in the form of increased eagerness for certain orders of which he has been largely deprived and a corresponding slight repugnance to those he has been chiefly receiving. My experiment of August 30th, 1913, affords a very perfect illustration of this. The drongo, having been deprived of Lepidoptera for some weeks, and having developed over-eagerness for them and disinclination for, in particular, Orthoptera, was fed for nearly a whole day on Lepidoptera alone. This was enough to tire him of them and to create a fresh eagerness for Orthoptera. The experiment—to "place" the butterfly *Crenis rosa*—was consequently unsuccessful.

Similarly, my rats, and, at one period, my lemur, would be so ravenous for

animal food after being deprived of it even for a day or two that their usual discrimination in relation to it vanished and they became, till their meat-hunger was satisfied, nearly useless for experiment in that particular direction.

As the result of my general experience, I would lay it down as, at any rate, a safe rule: "To ensure thoroughly reliable results provide a mixed diet and include as a fairly important item the order of insects with which it is proposed to experiment." Wherever, however, experimentation is on a sufficiently large scale and fairly continuous, the material used in it should alone be sufficient to obviate over-eagerness and too great lack of practice.

Further points. I made a point of always (four times a day) placing the birds' food in their trays myself and also of chatting much to them, with the result that they quickly became very friendly with the experimenter. At the same time, after the initial taming, I avoided the continual offering of dainties by hand, and would allow even their ordinary food to contain a certain proportion of such highly unpleasant insects as the bird might most frequently meet with in the wild state (as the grasshopper, *Lentula*, and the Meloid beetle, *Mylabris*). The cages were wire-fronted packing-cases, with the result that no bird could see what those in the other cages did; and, further, no complications arose with regard to the possible removal of insects by ants or the birds' attendant, excepting, I believe, in one unimportant instance. The cages were in proportion to the size and importance of the bird (the owl even having a whole small shed to herself); they were kept, when not in the sun, in a dry, airy, sheltered verandah, and they were cleaned out daily. Each bird, except where otherwise stated, had a cage to itself.

It may still be objected that however successful the experimenter may be in ameliorating its conditions, confinement must necessarily remain a highly unnatural state for so active an animal as a bird. It is still, therefore, exceedingly possible that my birds did *not* display the same preferences as they might have done in the wild state. I fully admit the possible justice of this criticism, and all I have left to reply to it is this:—

1. Each sufficiently tested bird was found, on the whole, to be exceedingly consistent.

2. There has been quite a strong general agreement in the order of preference, not only between individuals of the same species, but between different and quite unrelated species—so unrelated as a butcher-bird, a drongo, various Picarions, an owl, a hawk, and a francolin; also not only between the various birds themselves, but between these and a monkey, a chameleon, a beetle, an Orthopteron, a dragon-fly, and an Asilid, *in so far as these latter animals have been tested*. Thus *Acræinæ* (and certain beetles) have *always* been placed very low, *Mylothris* (and certain moths and grasshoppers) always just above them, *Belenois* and some *Lycænids* always next, and other *Lycænids* and *Pierines* and some *Nymphalini* and *Satyrine* genera and a skipper (*Cyclopides*) above these. Finally, came the yet higher grades, which included various

Nymphalinae and skippers, *Catopsilia*, various grasshoppers and Noctuids, etc. I think that the only striking exception was in the case of our commonest bulbul (*Pycnonotus layardi*). Two birds of this species that I tried both tended to place Pierinae generally particularly low, and one of them at any rate placed Danainae unusually high. This departure from the more usual order may, of course, have been a case of vitiation due to captivity, but I should rather hesitate to accept that explanation myself. It is more probably a case of specialization—or, if the peculiarity be confined to individuals, it may be analogous to the differential results on the natives who eat them of the larvæ of the moth *Anaphe panda*.

I would in any case like to make it quite clear that I am not referring to the larger preferences as between Orders. Thus, if any species specializes on Diptera, it is likely to place these insects generally far higher than will a bird that is not to the same extent a Dipteran eater: *cf.* the contrast in this respect between my drongos and my rollers.

3. Newly-captured birds have, in so far as their preferences have been ascertained, confirmed long-caged individuals, with only the occasional and relatively slight transpositions that may be expected even between two wild examples of the same species. In this connection Roller C's list may usefully be compared with that of Roller B.

4. My tame ground-hornbills, roaming always unconfined and not fed at the house at all, had much the same preferences, in so far as they were ascertained—as, *e. g.*, my captive rollers.

5. Such preferences as I have elicited from wild birds—and they have been fairly numerous—also go to bear out the views of my captive birds.

This is the case for the *reliability* of my experiments. I will now frankly state those points in which I believe them to be *not* entirely reliable.

1. *Through relative lack of exercise.* I have evidence—not conclusive, for the species were not the same, but certainly I think fairly strong—in favour of the view that unconfined birds, probably with the digestion born of exercise and of general greater enjoyment of life, may more readily and frequently become hungry enough to eat highly indigestible insects than even non-fretting captive birds. This, as will at once be seen by a study of my experiments on them, is not equivalent to saying that they do not discriminate, or to saying that the order of their preferences may not be approximately the same as those of captive birds of the same species.

2. *Through relative lack of practice.* It being obviously impossible, however much trouble one may go to, to provide the *full* amount of practice enjoyed by a wild individual, mistakes from lack of it are likely to be especially frequent amongst captive animals.

Mistaken tastings, for instance. Not that for the purpose of these experiments anything but mistaken *eatings* matters, for a rejection is as good as, or better than, a refusal; and mistaken eatings are rare even amongst

captives, so accurate and instinctive does the judgment by taste even among young birds become after a very little practice.

Mistaken refusals too. Thus it seems quite probable that, given an equally perfect view, a wild bird would, as the result of greater practice, distinguish between the commoner models and mimics somewhat more readily on the average than did my more long-caged birds. Yet, as I will show, even wild birds are deceived—and they seldom have so good a view as I used to go out of my way to provide for my captive birds.

3. *Through surfeit in a particular direction.* I have had cases—very few indeed that mattered—in which probable over-eagerness for a particular order has been displayed. To these cases I will draw special attention as I come to them.

The above are three difficulties that are likely to confront even a careful experimenter on captive animals. The first two can be partly remedied and entirely allowed for, and the third can be remedied: none of them need be allowed to vitiate one's deductions in any appreciable degree.

A fourth difficulty is worth stating here, though it has certainly had no especial connection with captivity. The animal experimented on would sometimes appear suddenly to awaken to a realization of greater appetite; it would fall back (sometimes with an actual "brisking up" of manner, which at once gave the clue) to a point already left behind and once more begin to take things that were already becoming unacceptable to it. Even amongst my insectivorous birds this was probably in most cases equivalent to that marked increase in appetite that I later found it possible—and useful—to provoke at will in my carnivorous animals by the offering of something sufficiently pleasant to stimulate, it would seem, a flow of the digestive secretions. Conversely, repletion—or the symptoms of it—might be produced prematurely by the eating (in, at any rate, one of my mammals merely the smelling) of some unduly indigestible species of prey.

To this phenomenon—the sudden stimulation or inhibition of the gastric secretion—may be attributed, I believe, nearly all the cases of apparent inconsistency that have occurred in the course of these experiments. Its occurrence demands increased caution in the deduction of preferences generally, but, as I have said, there seems no reason to suppose that it is a phenomenon peculiar to or aggravated by the captive state.

In conclusion, it must in all fairness be acknowledged that the only *absolute* proof that a captive animal's preferences are the same as those of that animal in the wild state would be that afforded by a testing of the preferences of a single individual, (1) in the wild state, (2) after capture; and I have often regretted that it did not occur to me to attempt this in the case of my wild bush-shrike (*Dryoscopus guttatus*). But even the evidence I have obtained (and referred to above), namely a rough general agreement between unrelated species in captivity and, yet more important, the rough confirmation of these

captives' preferences by wild individuals, albeit of other species, seems to me to be of a particularly cogent nature.

C. METHODS OF EXPERIMENT AND DEDUCTION.

The plan on which I started (on Dec. 6th, 1908) was as follows :—

First to offer each of my captive animals as large a series as possible of every available species of butterfly, and then, having thus ensured an adequate knowledge of their butterflies by these animals, to carry out on each a series of preference experiments by repeatedly placing together on the floor of the cage a few freshly-killed butterflies of different species and noting which were chosen.

For a time I was less successful than I had hoped, though, clinging at first to certain preconceived ideas and as yet knowing little of the factors that should have been allowed for in shaping the experiments, I did not realize this then. I now find many of my earlier experiments very disappointing reading indeed, and it is with a feeling of surprise at my own slowness and ineptitude that I realize that I largely wasted five months (Dec. 6 to May 11), 534 experiments, and many thousands of butterflies in merely learning to experiment. For it was apparently only towards the latter date that I was commencing to realize at all sufficiently the vital necessity for keeping in some sort of touch throughout an experiment with the state of the animal's appetite. It is also possible that the scale on which I attempted my series-offering constituted rather a counsel of perfection : at all events, from one cause or another, it was only in the case of a small proportion of my earlier animals that I ever arrived at the second or true preference-experiment stage.

Finally, the above-described method of preference experiment seemed when I first tried it to lead to results as difficult of interpretation as those that Colonel Manders (Proc. Zool. Soc. London, Sept. 1911, pp. 696-749) obtained by the same method in Ceylon. I have since (by repeated observation on several species of birds, wild and tame, and one mammal—*Petrodromus tetradactylus*) found the explanation to be that an insectivorous animal, given a choice, either fails to exercise it, as between the things he is hungry enough for and merely picks up each as it comes, or, when he does exercise it, tends to select the *largest* object that he is at the moment hungry enough to eat : were he hungry enough for *Amauris dominicanus* he would probably take it in preference to *Precis cebrenae*. When this is realized and allowed for, this method, first suggested to me by Mr. Marshall, is not only exceedingly useful but probably the only one that can in most cases be satisfactorily employed in dealing with wild birds. I had, however, in any case attempted very little in the way of preference experiments at all before May 12th, 1909, when I commenced a short series of experiments on one of my buzzard-eagles (*Asturina monogrammica*), in the course of which I evolved what is now my more usual method of eliciting preferences,

This method, apart from its general ease and sureness and its capacity for being combined with the offering, where necessary, of large series, itself incidentally keeps the experimenter in touch with the state of the animal's appetite and possesses the further inestimable advantage of *practically eliminating the personal factor*. There is no absolute need to mention the animal's manner: the bird's acceptance of one insect immediately after the refusal of another is usually enough to indicate their relative value in its estimation. Thus where an animal, hungry after a fast or empty after voiding a pellet, eats Z but (after, say, a grasshopper) refuses a second Z yet eats a Y, refuses a Y but eats an X, refuses an X but eats a W, and so on up to A, a second or third individual of which species he rejects or refuses, while treating in the same way an insect that he has been found to eat habitually with eagerness up to actual repletion-point, there can be no difference of opinion amongst even a hundred spectators of the experiment. All, whatever their bias and however differently they might have construed the bird's manner of acceptance or rejection, are likely to agree, on the whole, that A (in spite of the bird's final repugnance to it) is probably a great favourite and Z (in spite of the eagerness of the first acceptance) very much the reverse, and that the bird's preferences, in so far as they can be judged from that single experiment, are probably in alphabetical order. Should these results have been repeated in subsequent experiments, perhaps in very many subsequent experiments and at varying intervals of time, and sufficiently checked by changes in the order of offering, the probability of their truly representing the bird's preferences will have been increased to something like a certainty. A complicating factor that I have already referred to—the stimulation of the appetite by a very welcome offering or its inhibition by a very unwelcome one—will, of course, have to be watched for, but I have found the latter, at any rate, of less importance here than in the case of my carnivorous mammals.

It is on results obtained by the above relatively mechanical method that I have placed my main reliance. At the same time, as will be seen, I have not hesitated, in numerous instances, to base deductions on the indications that are so often afforded by an animal's manner. This method is less reliable than the other in that it affords an opportunity for the entry of differences of opinion and unconscious personal bias, but, used with due caution (as I have, I hope, used it) and especially with a knowledge of the state of the animal's appetite (for without this it is useless), it becomes after practice far too valuable a source of evidence to be entirely neglected.

I would go further, and say that without a knowledge of the animal's state of appetite (best gauged by what of known value the bird will or will not at the moment accept) it is not only useless—it may be hopelessly misleading. A bird will frequently reject with, apparently, some disgust an object that if slightly hungrier he would have eaten with apparent relish; he will

sometimes when quite replete reject even his greatest favourites with signs of displeasure, or when really hungry accept the most "nauseous" insects with every gesture of eagerness: and it is only when the experimenter is aware how hungry or otherwise the bird is that he will know just how much value to attach to these demonstrations.

Some of these actions have obviously in themselves no relation whatsoever to the animal's likes and dislikes—such as the battering and the mastication referred to above: yet (as I have indicated) they are well worth watching for the manner in which they are performed. In this category comes the wiping of the bill. It is a very usual action after food has been eaten, particularly if it has required much preparation and left juice or fluff on the bill. It may even be continued at intervals, as I have seen, for some time afterwards, and, I fully agree, does not necessarily indicate the very smallest dislike of the object swallowed. Yet there is a wiping of the bill—and it is not, I think, always very difficult to recognize for the experimenter who has come to know it—that does seem to indicate dislike (when an insect has been tried), and there is also a wiping of the bill that may accompany refusal without trial. With my kingfisher and at least two of my bulbuls this form of refusal (without tasting) of a proffered insect was by no means unusual, and it occurred in other birds too; and I have on a few occasions, by merely holding up a very low-grade insect in view of all the cages at a time when the various occupants were by no means hungry enough for it, produced the simultaneous vigorous wiping of several bills. I have seen my kingfisher thus wipe his bill repeatedly when an *Amauris albimaculata* or *lobengula* merely entered the verandah and remained flying about in it for two or three minutes: it was one of the methods adopted by my older wood-hoopoe (*Irrisor erythrorhynchus*) apparently to dissuade a younger bird from eating a *Danaida*; and much bill-rubbing is sometimes indulged in before and in the intervals of attempts to bring up an insect, the eating of which has resulted in nausea. This last instance indeed would seem to suggest that there may be a simple physiological explanation at the back of all these cases of bill-wiping, namely, the abundant reflex secretion of saliva that at any rate in man and certain other mammals is known to accompany actual nausea or the sight of objects that experience or training has suggested to be of a nauseating character. From cases like that of the wood-hoopoe one might even suspect, were one inclined to theorize, that as spitting in man has gone on from (quite possibly) this beginning to become a conventional sign of contempt, so bill-wiping may have become stereotyped in some bird-languages as, *inter alia*, a signal of unacceptability or warning.

That there are cases in which it is by no means easy to decide between two or more possible motives it would be foolish to deny. Thus I at first tended largely to put down to grave suspicion actions that I have since learnt to attribute in most cases to mere disinclination—or mere initial caution. Even

to this day, as will be apparent from some of the experiments to be described, I would not feel at all certain of being able to distinguish between these two motives in every case.

Number of Trials, etc. : It will be seen that the results of single trials in these experiments have been sometimes by no means final, and that I nowhere place the same reliance on them that I do on the mutually corroborative results of several trials. It was in order to avoid so far as possible the suspicion that must necessarily attach to single tastings that the experiments were, as already indicated, attempted on a fairly large scale. Again, in numerous instances (indicated often by the word "persistently"), I have offered and re-offered and *re-offered* even an individual insect with the greatest insistence in order to make sure that its refusal was thoroughly genuine and well-considered. And throughout I have obtained that consistency of result and that same general range of preferences from *Acræinæ*, etc., upwards that I have referred to earlier.

My method of offering, I ought to explain, was, unless otherwise stated, to bring each insect up close to the bird's bill (or mammal's mouth), usually by the forceps. This ensured a definite acceptance or refusal—there was no possibility of the insect remaining unnoticed. It was, of course, impracticable in the case of the wild birds.

"Inedibility" ; "Unpalatability." For reasons which will, I think, be appreciated by anyone studying these experiments, I cannot help regarding the use of the terms "edible" and "inedible" without qualification as somewhat highly misleading. It is true that a large *Brachycerus* is inedible to a bulbul, and even to a roller, but it is not inedible to a bird, large enough to swallow it, whose bill is capable of crushing it (e. g., *Bucorax*), or whose digestive apparatus is capable of dealing with it uncrushed (e. g., *Numida* . An *Amauris* or *Acræa* is unacceptable at most times to insect-enemies generally, but it is by no means "inedible." Given the appropriate degree of gastric activity it may even be highly acceptable to any of them. The difference between it and, say, a *Precis cebrene* is probably simply one of frequency of attack, but that difference may be a highly important one. Thus, even though it be itself very frequently attacked, a species that is only acceptable when the crop is empty is likely (other things being equal) to be considerably less frequently attacked than one that is acceptable at all stages ; and even this advantage is sufficiently obvious to render it intelligible that it may be of benefit to the latter insect to be sometimes mistaken for the former. For how great the benefit might be, see (for example) experiment 29, in which no less than 40 butterflies, including 14 large *Charaxes*, were eaten by Roller B after she had tried and rejected a *Mylothris agathina*, and 37 butterflies, including 12 large *Charaxes*, after her similar rejection of a *Terias*. I could multiply instances as striking or possibly better, and there is nothing I think that more vividly brings home to

one the reality and probable importance of the defence that is known as unpalatability.

To illustrate, however, my remarks on "edibility" (and incidentally to supply the reply to a question raised by Mr. McAtee), I may say that my shrikes not only ate when sufficiently hungry such very low-grade insects as *Mylabris* and *Zonocerus* (often, it is true, with many signs of dislike), but would even, when insufficiently hungry for them, impale them sometimes for future use. If one were taken off the spike and re-offered they would reject or re-impale it, and yet immediately after doing so they would, given the chance, make a large meal off certain other insects. If they were now offered one of *these* when becoming too replete for it and no spike were vacant, they would often remove and throw away the *Zonocerus* or *Mylabris* and replace it by the higher-grade insect, and this in turn might be replaced later by a still more welcome species. I have never seen the order reversed. My cat, even when hungry, would similarly continue for some time to play with or often re-visit a "nauseous" bird or small mammal for which he had no present use and would eventually perhaps eat it—his appetite seeming to be gradually stimulated by the playing with it. But he would in the meantime at once relinquish it if offered more acceptable prey and would make an immediate meal off the latter. The last remark also applies, roughly, to my owl. She, too, would otherwise hold for a long time prey too low-grade to be of use to her in her then state of appetite, thus seeming to show, like the shrikes and the cat, that she realized that it would become perfectly edible under certain gastric conditions that had yet to arrive. Not that either birds of prey or butcher-birds are continually killing animals that they are not at the moment hungry enough for, however provident they may sometimes show themselves over them when they *have* killed them. So at least I would conclude from the very numerous refusals that I have witnessed on the part of hawks and *Lanius* in the wild state and from the fact that with my captive birds of the latter genus rejections were far more numerous than impalements.

Whether the term "unpalatability" sufficiently describes such protection as is possessed by an *Acræa* or *Zonocerus* I will discuss fully in finally summing up the results of my experiments. I have, I think, a good deal of evidence in favour of the view that smells and tastes, like appearance, are of use in averting the eating of their possessor mainly when they have become associated in the enemy's mind with unpleasantness of a more fundamental character. This is probably, in most cases, indigestibility, greater or less, conquerable by a greater or less degree of gastric activity.

Possible errors and past mistakes: The working out (and in most cases re-casting) of the conclusions from the different preference experiments has, owing to pressure of other work, been spread over a very considerable period and has at all times been greatly interrupted. It is very possible, therefore, that, in spite of care, mistakes may be present. Should any such be detected

by my readers, I should be grateful if they would kindly draw my attention to them. The main method of deduction has been explained already: it is based on the assumption that if B is refused but A then eaten, A is probably (other things being equal) at that moment preferred to B. If A had been first eaten and B *then* refused, the probability would have been that A was at any rate not appreciably *less* liked than B. It would be unsafe to go further unless a marked difference in manner justified it.

Again, it will be noticed that up to a fairly late date in May, 1909, by which time I was beginning to adopt more critical methods, the experiments (as I now interpret them) were very barren of results. I have already stated the reasons for this. In this relatively unproductive category come all the experiments on Roller A and approximately the first fifteen on Roller B. At the same time the further advance from even my later experiments on the latter bird and on C to my latest experiments of all, to be published in a future paper, was probably nearly as great, for it was not until this latest period that I realized the effect on appetite of "the preceding offering" and shaped my experiments accordingly. "Refused A ate B, refused A ate C, refused A ate D" now takes the place of "refused A, ate B, C and D," B's possible stimulatory influence making it not quite safe to infer from the last formula that C and D as well as B were preferred to A. Much evidence that at the time I had regarded as good is thus rendered doubtful and I am refraining from using it.

As for the discarded conclusions from my very early experiments, I freely confess, for any who may still find preferences hard to believe in, that I too at first started out, not, it is true, with a disbelief in "unpalatability" (for, amongst other things, I had had the advantage of witnessing some of Mr. Marshall's experiments in 1899 on animals of my own), but at any rate with much confidence, founded on what then seemed good evidence, that very little unpalatability would be found to occur in our *Satyrinæ*, *Nymphaliniæ*, *Pierinæ*, or *Lycænidæ*. I confess further that it took quite a good deal of evidence to convince me of the contrary, the rejecting animal being always, I could not help for a time suspecting, "in a capricious mood" or "reckless," or perhaps "unsuitable"—at any rate, anything rather than right. I suppose that nearly every investigator of such a subject is likely at first to pass through a shorter or longer "refractory" stage of this kind before he shakes off his first opinions and, throwing everything into the melting-pot, begins to learn.

It will be seen later that this was not the only idea of which my animals soon disabused me, and, as a complete cure for too great confidence in any particular view, I can thoroughly recommend a good long course of special experimentation.

For the explanation of the few abbreviations that, to save space and endless repetition, I have used in the course of this paper, I must refer the

reader to the end of my introductory note to Section 3, and, again, to the commencement of Experiment 494.

NOTE.—I had already long drafted this introduction, with its reply to a hypothetical critic and its description of the precautions taken to render the experiments and their interpretation as reliable as possible, when my "critic" suddenly materialized. For I was lent by Mr. Marshall a copy of Mr. W. L. McAtee's very comprehensive if somewhat over-vigorous criticism (Proc. Ac. Nat. Sci. Philad. 1912, pp. 281-364) of "The Experimental Method of Testing the Efficiency of Warning and Cryptic Coloration in protecting Animals from their Enemies."

Having read it, I decided, for the sake of completeness, to expand my original statement by the inclusion of points raised by Mr. McAtee that had not occurred to me as difficulties, but of which it seemed to me that my experiments had in any case supplied the explanation, and I hereby gladly acknowledge my indebtedness for them. I have, I think, omitted none of any importance, and I believe that Mr. McAtee, in view of the facts stated and yet to be published that were not in his possession when he wrote, is likely to be the first to agree that the experimental method is perhaps less unreliable, and those on whom he chiefly concentrated his criticism less indifferent to the necessity for abundant evidence than he had supposed, that the "strongly contradictory conclusions different experimenters have drawn" (p. 357) were probably merely the result of their not having carried their experiments quite far enough, and that any unintentional misinterpretation that may have resulted from the same cause has been, at worst, by no means confined to those who favoured the selectionist view.

2. EXPERIMENTS ON CAPTIVE EUROPEAN ROLLERS (*CORACIAS GARRULUS*, Linn.).

A. INTRODUCTION.

1. *Probable food in the wild state.* We have four species of *Coracias* (and one of *Eurystomus*) at or near Chirinda, and of these *Coracias garrulus* is usually by far the commonest during its stay.

The other three species are apparently residents, and the four together (or even *C. garrulus* alone while here) are probably sufficiently numerous to contribute somewhat to the selective factors operating on whatever insects they chiefly prey upon.

Migratory locusts, both larval and winged, various grasshoppers (including *Phymateus*), Locustids, weevils and other beetles including *Anthia pachyoma*, lizards, small snakes, mice (the natives often bait their roller-traps with these), crabs, centipedes, scorpions, cicadas, Mantidæ, fly-maggots, and termites have been found by various observers in the stomachs of birds of this genus. At least three of its local members possess much the same feeding-habits, remaining perched on the summit or on one of the more prominent side-branches of a tree or shrub, quietly waiting for their food to pass. Probably more often than not it is a beetle or grasshopper wandering over the ground that is pounced on, but migratory locusts are followed and captured on the wing:

I have several times seen *Coracias caudatus* take up its position on successive low trees close to a grass-fire and thence dash in often successful pursuit of the various insects that were flying desperately from the flames; and I have seen *C. garrulus* display such dexterity in capturing an active insect on the wing that I should not be entirely surprised were future observation to confirm Mr. Bryden's statement ('Nature and Sport in South Africa,' p. 64) that "Rollers are great hawkers of flying insects, especially butterflies." Marshall (Trans. Ent. Soc. 1909, pp. 360 and 369) gives four separate instances, including the quotation from Bryden, of attacks on butterflies by wild individuals of this genus and I shall myself be able to add slightly to these records. Then "Seventeen," my black superintendent, an intelligent native of Inyambane who has been with me for many years, when I asked him the question "Do birds *generally* feed much on butterflies?" replied that he was less sure about the others but that rollers at any rate did—*greatly*. He stated that he had seen instances himself and that it was in any case a matter of common knowledge amongst the natives of his tribe, who acted on the knowledge to the extent of sometimes baiting their roller-traps with butterflies; and he gave me the definite and unusually interesting record that I shall include in a later section of this paper—of a roller that day after day frequented the same dead branch for the purpose of attacking therefrom the butterflies passing to and from some fruit close by. Furthermore, my captive rollers showed, I think, no special repugnance to butterflies as against insects of other orders. It may be objected to this that neither did my captive lemur show any great repugnance to porridge-and-milk—which, nevertheless, constitutes no proof that he had been in the habit of eating porridge-and-milk in the wild state. True, but it *may* constitute an indication that he would possibly have eaten porridge-and-milk in the wild state had he met with it and been able to obtain it; and there can be no reasonable doubt that my rollers *had* thus met with butterflies and were, moreover, probably quite capable of often capturing on the wing even such active insects as the larger *Charaxes* (*vide* my wild bird records). C, the only roller on whom I sufficiently tested the point, displayed what could only, I thought, be interpreted as a very good previous knowledge of his butterflies, while, to reinforce my reply to the lemur argument, I may add that during two separate periods a wild lemur of the same species as my caged one (*Galago crassicaudatus*, Geoff.) formed the habit of nightly visiting our verandahs and stealing from the shelves and tables non-indigenous fruits and the cream from my wife's milk-basins. The first visitations were at a time of year when *Galago's* natural food was especially abundant, and the whole incident (and others I could quote) seems to me perhaps somewhat to weaken the possible contention that it was only under conditions of captivity that my lemur would have shown no repugnance to such food—or my rollers to butterflies.

On the whole, I feel fairly satisfied that *Coracias garrulus* was a sufficiently

suitable species on which to carry out what was, perhaps, my most important series of butterfly experiments.

In view of its relative importance I would like again to emphasize the fact that from the outset I studied the matter of food and spared no pains to provide my captive rollers with a thoroughly varied diet on as natural lines as I could devise. A reference to the list I have already given will show, I think, that I was probably not entirely unsuccessful in this.

2. *The Experiments.* All three of my rollers (A, B, and C) were from the outset remarkably tame and fearless, showing relatively little alarm at passing dogs or servants, and accepting food from the forceps almost at once. They were lethargic birds. B, in particular (the bird on which most of my experiments were carried out), had a very large cage and plenty of perches, but excepting at the northward migration-time (when she sometimes was restless at night) she took very little exercise, remaining as a rule quietly perched in one place, excepting when she descended to eat or drink or shifted her position with the sunlight, of which she was very fond. This was, of course, a pity, and it was quite likely, owing to this lack of exercise, that she relatively seldom, even after a fast, developed so ravenous an appetite as to eat *Acraëne* readily. She ate heartily, nevertheless, and kept in excellent health and condition throughout.

All three birds expressed their sentiments with regard to the offerings made to them with, usually, a lack of ambiguity that rendered them exceedingly satisfactory subjects for the purpose in hand. All three also appeared to be exceedingly cautious tasters and, though often emphatic enough in their refusals, seldom swallowed an insect, however small or however well-known, without first more or less crushing it (often running it through their bill from side to side as they did so). That is to say, very few insects were eaten without a preliminary tasting, the bird maintaining a highly judicial calmness and precision of demeanour that tended to inspire the onlooker with a certain amount of confidence even while it amused him.

B. EXPERIMENTS ON *CORACIAS GARRULUS*. A.

1909. *Feb.* 23. An adult European roller brought me by a woman who had, she said, just limed it. Accepted food from the forceps.

Exp. 1.—*Feb.* 24. Offered the common mud-coloured beetle, with hard elytra, the roller crushed it very slightly with one bite of the point of his bill, and at once swallowed it down, tried and at once rejected a *Neptunides polychrous*, shaking his head after doing so (the same individual had already been rejected by *Centropus burchelli*, A), crushed a few times with the point of his bill, and finally rejected a *Papilio lyæus* with wings, and, on my offering a second without wings, masticated it as before and swallowed it. No sign of dislike was shown, but a

second wingless *P. lyæus* was bitten two or three times and rejected. The bird soon afterwards, however, descended and ate it, still neglecting that with wings and the *Neptunides*; both were lying on the floor of the cage. A *Charaxes brutus natalensis* without wings was then well crushed in the bird's bill, but in the end rejected. Half an hour later (I do not know whether the bird had fed in the meantime) I took it out from amongst the other food on the cage-floor and reoffered it. It was again well masticated and thrown back into the throat to be swallowed, but brought out again and rejected, the bird shaking his head afterwards.

[Nothing is said of the state of the bird's appetite. The fact that there was food in the cage throughout does not necessarily in this species prove repletion, but if by any chance Roller A's sentiments towards *Charaxes brutus* (and other large *Charaxes*) resembled that of my other two rollers, then its rejection was practically tantamount to a declaration of nearly complete disinclination for food, whether through repletion or some other cause. In that case the Tenebrionid and the wingless *P. lyæus*, both eaten up to the point of complete disinclination, might fairly be regarded as having been probably found highly acceptable, while the rejection of the *Neptunides* and of the winged *P. lyæus* need not necessarily indicate any very great unacceptability for them. A preference may perhaps have been indicated in the fact that the *Neptunides* was rejected with promptitude, the *P. lyæus* with wings more waveringly; no preference necessarily attaches to the Tenebrionid, seeing that it was already eaten before the other insects of the experiment were offered. It may, however, be inferred that wingless *P. lyæus* was preferred both to the *Neptunides* and to *P. lyæus* with wings: a good instance of what I have found throughout my experiments—that a butterfly without wings tends to be slightly preferred to the same butterfly with those obstacles still attached.]

Exp. 2.—Feb. 25. Tasted with caution and rejected with signs of disgust a larva of *Atella phalantha*.

[Experiment useless, seeing that nothing is stated which might even approximately indicate the state of the bird's appetite.]

Later in the day, noticing that yesterday's *Papilio lyæus* and *Charaxes brutus* were still, with a good deal of other food, lying uneaten in the cage, I offered a ♂ *Papilio lyæus* without wings. It was well crushed and readily eaten. On my now offering a second, however, the bird shook his head and at first took no more notice of it, finally, however, accepting, crushing, and swallowing it. I now offered him a *Precis natalensis* ⊕ f. with the brilliant upper surface of the wings displayed. The bird refused obstinately to have anything to do with it, shaking his head and clapping his bill violently whenever I brought it close up to it. I now offered two butterflies of the same species with all wings removed. Each was crushed at once and swallowed with the greatest apparent relish. On my presenting a yellow ♀ of *Catopsilia florella* with all wings attached, the roller hesitated, then took it in his bill in a half-hearted way, the butterfly at once escaping and fluttering about the cage while the bird settled down and took very little further notice of it.

I extracted and reoffered it, but it was again taken hesitatingly and once more escaped. I then offered a second yellow ♀, this time stripped of wings; the bird ate it readily enough after mastication.

I now offered a *Danaida chrysippus* with wings. The roller's behaviour on seeing it was most striking. He ruffled up the feathers of his crest and mantle, drew himself up and looked most ferocious, shaking his head with the greatest vehemence as I continued to hold the butterfly towards him.

On my offering immediately afterwards an *Acræa acara* ♀ with wings, the bird at first simply ignored the butterfly and later shook his head repeatedly. On my continuing to press it, he indulged in his own equivalent of the owl's "apologetic nibbling" several times, pretending to close his bill lightly over the butterfly and each time drawing back with a shake of the head and a clap of the bill and looking straight at me as though to explain that what I was offering him was not acceptable. A moth (*Xanthospilopteryx superba*), without smell but with wings, was now refused without tasting. On its being reoffered without wings, the bird leant forward, barely closed his bill on it, and at once drew back.

I now turned and offered the moth to *Lanius collurio*, which ate it readily enough. Immediately afterwards the roller accepted, crushed, and readily ate a *Papilio lyceus* and five *Precis natalensis* ⊕ in rapid succession, all without wings.

[Apparently, at the commencement of the experiment, only just hungry enough to eat wingless *P. lyceus*, eaten up to *Charaxes* point on Feb. 24. Wingless *Precis natalensis* ⊕ and wingless *Catopsilia florella* would appear to have been at least as acceptable, in the same state of appetite, as the *Papilio*. I surmised that the roller's behaviour towards the *Precis* with wings perhaps indicated that it reminded him of, e. g., *Acræa acara*. This is exceedingly possible, especially in view of the results of other experiments in which these two butterflies were used, but an alternative possible explanation exists—"wings versus no wings,"—which is still more applicable to the bird's treatment of stiff-winged *C. florella*.

I also at the time of the experiment judged the roller's refusal to taste *Danaida chrysippus*, *Acræa acara*, and the *Xanthospilopteryx* to indicate a probable previous acquaintance with those insects. Once more this is exceedingly possible. Alternatively it might be argued that the roller was perhaps so replete as to regard with boredom the eating of any large-winged butterfly with the wings attached. Nevertheless, the special refusal of the *Danaida*, with every sign that in my subsequent long series of experiments on birds of the same species I came to associate with the very greatest unacceptability, should be given full weight.

Usually acceptable butterflies of distinctive appearance should have been offered *with wings* after the refusal of the *Danaida*, etc.

The *Catopsilia* refused earlier is useless to us, seeing that yellow ♀ *C. florella* with wings has frequently been an object of suspicion in the course of my experiments, even when the birds were quite hungry enough to be in nowise deterred by wings pure and simple.

At the end of the experiment a preference was shown for wingless *P. lyceus* and *Precis natalensis* as against wingless *Xanthospilopteryx superba*. The fact that no less than five of the *Precis* were eaten in addition to the *Papilio* shows that, actually, the roller had *not* been quite replete.]

Exp. 3.—*Feb. 27.* Bird very restless to-day, off his feed, and spending all his time in trying to get out. On my offering him by forceps larval migratory locusts and the larvæ of, probably, *Rhabdotis aulica*, he often simply crushed them slightly and tossed them away, treating similarly wingless *Atella phalantha*, *Charaxes zoolina*, and *Charaxes brutus natalensis*. Later I gave him a wingless *Papilio lyæus*. He crushed and dropped it the first time, but again crushed it on being reoffered, and this time swallowed it. A second, however, after being for some time refused without tasting, was crushed and tossed away, then on being reoffered crushed and swallowed it. Two *Precis natalensis* \oplus , both without wings, were crushed and swallowed without hesitation.

[Any experiment on a bird in this mood was likely to be simply wasted, but the roller's apparent preference (deducible, perhaps, from the difference in manner) for *P. natalensis* \oplus as against *P. lyæus* may possibly be worth noting for comparison with future and surer results.]

Exp. 4.—*Feb. 28.* Plenty of food in the cage, but the bird was still rather chafing at confinement and it was not easy to secure his attention continuously. Thus an average interval of three or four minutes elapsed between his acceptances down to the *Precis ceryne*, inclusive. The last three trials were in quick succession.

The abdomen of a ♀ *Hypolimnas misippus*, rejected by *Lanius collaris*, was well crushed and swallowed without hesitation, as were also a *Precis artaxia*, six *Precis natalensis* \oplus , and two *Precis ceryne*. The bird now crushed slightly in the point of his bill and tossed away an *Atella phalantha*, crushed and readily ate a *Precis natalensis* \oplus , and once more rejected the *Atella phalantha*. All the butterflies in this experiment were offered without wings.

[*Precis natalensis* \oplus was apparently very distinctly preferred to *Atella phalantha*, but the mood of the bird enjoins caution in drawing any conclusions from this experiment.]

Exp. 5.—*Mar. 3.* The roller, placid now and eating well, readily accepted and ate three *Papilio lyæus*, refused a fourth, then after an interval ate four more.

[An instance probably of the effect of subsidence resulting from digestion, the bird being thus enabled to return to an insect that shortly before had become unacceptable: cf. other experiments, *passim*.

Seeing that only one species of insect was offered and that no good indication is given of the state of the bird's appetite, nothing can be deduced from this experiment of the pleasantness or otherwise of *P. lyæus*.]

Conclusions from Experiments on Coracias garrulus, A :—The conclusions have been stated at the end of each experiment, and strike me as neither sufficiently numerous nor sufficiently secure to be worth summarizing here. No attempt seems to have been made at any time to ascertain the exact state of the bird's appetite, and on two days he was experimented on when, owing to his unsuitable mood, he should have been left alone. It must be remembered, however, that these experiments were intended not as preference experiments but to accustom

the bird to the various species of butterflies, his preferences in which I hoped to ascertain later. That the experiments proceeded no further was due to his premature escape.

C. *CORACIAS GARRULUS*. B. EARLY EXPERIMENTS.

1909. Mar. 7. Another adult European roller was limed and brought to me this afternoon.

[There is very little to be deduced from the following fifteen experiments—to May 18,—though they mostly afford illustrations of the phenomenon commented on for Roller A on March 3. In any case, neither they nor those on A were intended as preference experiments. These may perhaps be regarded as commencing, for this bird, on May 20. Those of April 1, 9, and 15 were “mimicry” experiments.

In connection with those experiments that commence with “Plenty of food uneaten in cage,” I may remark that I had probably at that period still to realize that this roller (unlike some of my other birds) frequently allowed herself to get moderately empty before going down again to feed, and that abundance of uneaten food, however pleasant, did not therefore necessarily indicate approximate repletion.]

Exp. 6.—Mar. 9. Crushed and swallowed a wingless *Papilio lyceus*, refused the next, but accepted it three minutes later, and in this way ate seven in all with a refusal and about a three minutes’ interval between each. [She was evidently throughout barely hungry enough for them, a few minutes’ digestion after each refusal rendering her just hungry enough for another acceptance.]

Exp. 7.—Mar. 10. Crushed well, and, though she had not appeared to be hungry, ate with apparent relish a *Charaxes zoolina*, a *Charaxes guderiana*, and two *Charaxes candiope*, accepted with evident distinction a *Charaxes brutus natalensis*, crushed it slightly and dropped it. On my reoffering it ten minutes later she ate it readily, as also a second and a *Charaxes neanthes*.

[In concluding my account of this experiment I stated that I was left with the impression that the *Charaxes* were more enjoyed than the *Papilios* of the day before. I must confess, however, that there is nothing in the two experiments as recorded that necessarily indicates this, seeing that in neither case was the state of appetite definitely noted.]

Exp. 8.—Mar. 23. Had plenty of food in the cage and did not appear in the least hungry, but readily ate, after crushing each, five *Hypolimnas misippus* in rapid succession (a ♂ and four ♀). I now left five or eight minutes to allow for after-effects and offered two more ♀ ♀, both of which were readily accepted and eaten. Each butterfly in this experiment had one hindwing attached to ensure recognition by the bird.

[The same applies to all the following experiments, unless otherwise stated. The short interval for after-effects was a habit of mine at that time, plausible

enough but usually perfectly futile, for it merely gave the bird time to become just hungry enough for more of the same species.]

Exp. 9.—*Mar. 24.* In this experiment, which is certainly not worth quoting in detail, seven *Papilio lyæus* and five *P. demodocus* were eaten at intervals, refusals intervening. Some of the intervals were long, as the result, apparently, of great restlessness on the part of the roller, which kept moving about the cage. I regard the experiment as completely unreliable.

Exp. 10.—*Mar. 26.* Ate most readily a *Catopsilia florella* (just rejected by *Lobivanelus lateralis*), a *Papilio lyæus* ♂ (just refused by *Irrisor erythrorhynchus*), and five *Papilio demodocus* in quick succession. The sixth, however, was thrown away and the bird at once descended and ate a migratory locust or two. It later again refused the sixth *P. demodocus*, this time without tasting.

[It seems likely that it preferred the locusts to *P. demodocus*, but there is nothing to indicate the estimation in which it held the *Catopsilia* and the *P. lyæus* relatively either to each other, to *P. demodocus*, or the migratory locusts—nor to show how near to, or far from, actual repletion the bird still was when the latter were eaten.]

Exp. 11.—*Mar. 30.* The bird readily accepted from the forceps seven wingless *Charaxes candiope* in rapid succession, crushing each well before swallowing it. She was evidently, from her manner, becoming replete towards the end, and a wingless *Charaxes brutus* which I now offered was merely played with, being for quite a long time continually tossed up into the air and caught again as it descended. Finally, it was dropped. I reoffered it ten minutes later when it was eaten readily, as also a second and a third. The next was accepted and then listlessly dropped, but readily eaten on being reoffered a few minutes later, as was also a fifth. I now offered two more, also a *Charaxes candiope*, but the roller could not be persuaded to eat them. I accordingly left all three in the cage and on returning shortly afterwards found that the *candiope* had been eaten. In the evening, six hours later, one *brutus* was still left, but there had been quantities of other and varied food in the cage all the time, so that it may quite likely have been overlooked. Certainly the bird seemed to enjoy both species of *Charaxes*.

[I was probably correct in supposing the bird to be replete. Real repletion on the part of the roller was usually easy to recognize, and the playing with the prey, recorded above, was only indulged in at that stage. The eating of *C. candiope* and *C. brutus* right up to this point certainly seems to indicate that they were much liked—probably what we may call "Grade 1" insects. Subsequent refusals may well have been the result of sheer repletion, and there was nothing apparently to indicate that the *C. brutus* left in the cage was noticed by the bird.]

Exp. 12.—*Apr. 1.* A MIMICRY EXPERIMENT.—Tasted and at once rejected *Acræa areca* ♂, afterwards refusing decidedly and persistently to have anything to do with *Pseudacræa trimeni* ♀, *Acræa areca* ♀, and, once more, the *Pseudacræa trimeni*. On being shown an *Acræa acara*, however, it leant forward and

cautiously tasted it, promptly rejecting it. She then refused, without tasting, *Precis natalensis* ♂ f. and *Pseudacraea trimeni*, but accepted and ate a *Catopsilia florella* with the greatest readiness. All the butterflies in this experiment were offered with all wings attached and upper surface fully displayed.

[The bird certainly appeared to differentiate between the *Acraea acara* and the *Pseudacraea*, though less sure, apparently, of the latter and *Acraea areca*. It is possible that *Precis natalensis* escaped through its rough general likeness to *Acraea acara*. The two *Acraeas* were evidently definitely disliked—at any rate, relatively to the only butterfly eaten, *C. florella*. In this case no complication arises in connection with the presence or absence of wings (as happened in the similar experiment on Roller A). *C. florella*, the stiffest-winged of all, was swallowed, with its wings, at the very end of the experiment.]

Exp. 13.—Apr. 4. Plenty of other food in cage. Ate with the greatest readiness and no sign of dislike three *Papilio dardanus* ♀ f. *hippocoon*, each with one hindwing attached.

[As the roller's state of appetite was not definitely indicated, nothing useful can be deduced from this experiment.]

Exp. 14.—Apr. 5. INDEPENDENT EXPERIMENT BY MY WIFE.—Each butterfly, as usual, had one hindwing attached. The bird ate readily six *Precis cebrene* in rapid succession. My wife now waited five minutes for possible after-taste or after-effects to make themselves felt, and offered a seventh. It was recognized with evident pleasure and swallowed with as much apparent relish as its predecessors. The bird now ate in rapid succession six *Precis clelia*, showing actual and increasing eagerness and craning out for each butterfly as it appeared near the bars. After the usual short interval a seventh was offered. The bird, evidently recognizing it, reached out, snatched it from the forceps, and ate it with evident pleasure. She now readily accepted and ate two *Antanartia schoneia*, seven *Belenois*, and three *Salamis anacardii*, all in rapid succession.

The third *Salamis* was accidentally dropped from the forceps and the bird appeared quite concerned, leaning well over and gazing down at it. It was quickly picked up and reoffered, and this time eaten rapidly. A fourth *Salamis*, dead this time but not appreciably dry, was now offered, but the bird dropped it two or three times, each time after crushing it. She ate it, however, readily on its being reoffered fifteen minutes later. After this she readily ate two *Eurytela hiarbas*.

[The bird was probably fairly hungry at the commencement, but, seeing that there was no rejection early in the experiment by which one might have gauged her state of appetite, all that can be deduced is that, when hungry enough to do so, the roller would eat with every sign of relish the butterflies mentioned, including *Belenois* and *Precis*, in considerable numbers. There was nothing to indicate what grade any of the butterflies fall into, or how they stand relatively to one another.]

Exp. 15.—Apr. 9. A MIMICRY EXPERIMENT.—The roller tasted and promptly flung away *Amauris ochlea* and refused it without tasting on its being reoffered.

I now continued to offer it, four times in all, at short intervals, but the bird refused to have anything to do with it—in fact, simply ignored it. On the fifth occasion I offered *Hypolimnna wahlbergi* instead. The bird appeared at once to recognize that there was a difference, and, as in the case of the *A. acara* of the other day, leant forward to take it. At the last moment, however, she thought better of it and withdrew, without having actually touched it, and, though I continued to hold it to her, would take no further notice of it. *Papilio dardanus* ♀ f. *hippocoön* was now offered, but simply ignored.

In each case I had first fully displayed the colours of the butterfly just outside the bars before actually offering it. I had then held it through the bars by two wings, in the forceps, just in front of the bird, so as to allow it to flap.

She now ate with the greatest readiness six *Pyrameis cardui*, each with one wing attached, and, after the usual probably futile five minutes' interval for possible after-effects, a seventh; then accepted, crushed well, and ate with apparent relish the *Hypolimnna wahlbergi* with all wings removed, and after it the *Papilio dardanus* ♀ f. *hippocoön* similarly stripped.

Probably both these butterflies, as also *P. cardui*, were preferred to the *Amauris*.

[I apparently^{*} felt little doubt at the time that the bird at once detected the difference between *Amauris ochlea* and *Hypolimnna wahlbergi*. That she should have hesitated, nevertheless, to attack the latter might indicate (1) that so far as she was concerned *Amauris ochlea* is to some extent capable, even at a close view, of acting as protector of the mimics of *A. dominicanus*, (2) that the bird had already met with *A. dominicanus* and remembered it in time to refrain from attacking the *Hypolimnna* (and *Papilio*), (3) a general suspicion of large black and white butterflies, or (4) repletion to the point of not caring to swallow such large-winged insects. She has not usually hesitated to swallow even large species of *Charaxes*, wings and all, up to practically repletion-point, so that this fourth explanation does not seem likely to be the correct one, especially as she went on to eat with readiness and relish six *Pyrameis* with one wing and a *H. wahlbergi* and *Papilio* with none.]

Exp. 16.—*Apr. 10.* Had not long before retired to her perch after feeding on migratory locusts, etc. She, nevertheless, accepted and ate with apparent readiness and in quick succession, each after crushing it, a *Neptis agatha*, a ♂ *Hypolimnna misippus*, two *Belenois mesentina*, three *Belenois severina*, a *Mycalesis campina*, a *Precis natalensis* ☉, and a ♂ *Leuceronia thalassina*.

[This is quite a good instance of the fact that one should never assume a bird to be replete, or nearly so, unless one has actually fed it up to repletion by hand.

Several of the above butterflies have since proved to be acceptable to her by no means up to repletion-point.]

Exp. 17.—*Apr. 15.* A MIMICRY EXPERIMENT.—*Coracias garrulus* persistently refused *Acraea acara* without tasting and with emphatic shakes of the head. On my now offering *Pseudacraea trimeni*, a specimen that, except in size, was distinctly more like *acara* than *areca*, the bird at once leaned forward to take it,

but suddenly (as on previous occasions) thinking better of it, withdrew and thenceforth simply ignored it. She then refused ♀ *Acræa areca* with a sharp shake of the head.

[This *Pseudacræa* was, I noted, distinctly more like *Acræa acara* than that used in experiment 12, having a whitish area on the upper surface of each hindwing and a particularly strongly-marked subapical fulvous patch to the forewing. The bird, nevertheless, had seemed to discriminate between it and a very similarly-coloured specimen of *Acræa acara*, possibly partly as a result of the difference in size. She may, of course, have distinguished it equally from *Acræa areca* ♀. At any rate, its general likeness to one or both *Acræas* was probably sufficient to deter the bird, on second thoughts, from tasting it.

The last time the roller had seen either of these *Acræas* or any other butterfly with at all similar coloration was exactly fifteen days before, and before that again she had seen nothing at all resembling them for at least twenty-five days—that is to say, since March 7, the day on which she was captured. On April 1 she had tasted and rejected each, apparently distinguishing one from the other so far as appearance was concerned.

It is a pity that the roller's state of appetite was not ascertained here, as without that the suspicion must necessarily remain that she may have refused the insects through sheer repletion.]

Exp. 18.—*Apr. 28.* *Coracias garrulus* ate readily four *Pyrameis cardui* and refused the next, but five minutes later accepted equally readily and ate with evident relish two more and refused a third, and, five minutes later, again five more and again refused. All had wings.

[The refusals were probably due to the bird's having reached the repletion-stage for *Pyrameis*. Whether this was actual, absolute repletion-stage or not is unfortunately not indicated by the experiment as recorded.]

Exp. 19.—*May 12.* Crushed well and readily swallowed a *Belenois mesentina* (an individual already tasted and rejected by *Phyllostrophus flavistriatus* and *Emberiza orientalis* and refused without tasting by *Lanius lateralis*). No sign of dislike was shown, but a ♂ *Mylothris agathina* with decided sweet-brier smell had barely been tasted when it was emphatically flung away.

[It seems not unlikely that the *Mylothris* was found distinctly more unpleasant than the *Belenois*, though this conclusion must be regarded as based purely on the great contrast in manner. It would have been a safer conclusion had the *Belenois* been eaten after the *Mylothris* refusal.]

The conclusions to the first thirteen preference experiments on *C. garrulus*, B, were worked out at a date when I had not begun fully to appreciate the influence of "the preceding offering." This will have made so little difference, however, that, being pressed for time, I have not thought it worth while to recast them. Perhaps even the otherwise rather unnecessary detail in which they are stated is useful in emphasizing the vast difference between a low-grade insect and one that is eaten to repletion-point. Contrast, for example, *Melanitis leda* and *Mylothris yulei* in experiment 27.

D. *CORACIAS GARRULUS*. B. PREFERENCE EXPERIMENTS.

Exp. 20.—May 18. The bird appeared somewhat hungry. She eagerly ate a *Charaxes candiope*, a *Charaxes cithæron*, and a *Charaxes achæmenes*, then twice rejected, each time after tasting, a *Nychitona medusa* ♀, but readily ate another *Charaxes cithæron*.

[There seems little doubt that the *Nychitona*, for whatever reason, was liked distinctly less than the last *Charaxes*, and at any rate not better than *C. achæmenes*.]

Exp. 21.—May 20. I fed the bird to repletion by hand at the commencement of this experiment. She ate readily immediately after a large number of various grasshoppers etc., six *Charaxes brutus natalensis*, mostly with one wing attached, but refused a seventh, quite evidently through repletion.

Ten minutes later I again offered the seventh *Charaxes* with one wing attached. It was at once recognized and accepted with the greatest readiness, then well crushed and eaten. *Precis cebrene* and *Neptis goochi* (each with one wing) were, however, refused without tasting, the bird being probably in any case once more replete.

A few minutes later again she readily ate after the usual tasting a *Precis cebrene* without wings, tasted and rejected two wingless *Neptis goochi* in succession (they had already been tried and rejected by the Kingfisher), but for some time absolutely refused to touch a *Nychitona medusa* with one wing, of which she possibly retained unpleasant memories from two days before. Finally, however, she leant forward, tasted it with the greatest caution, and at once withdrew without removing it from the forceps. She now tasted and at once crushed and swallowed a *Precis cebrene* without wings, tasted and readily ate a *Melanitis leda*, tasted carefully and rejected a wingless *Belenois mesentina*. On my now offering a wingless *Papilio echerioides* ♂ the bird leant forward to take it, but struck short (accidentally), merely snapping off one of its antennæ. This she at once threw away with evident dislike, shaking her head repeatedly as I continued to hold the butterfly to her and refusing persistently to have anything more to do with it.

[I judged (no doubt, as usual, from the bird's growing difficulty in getting the insects down) that the *Charaxes* were eaten up to or very nearly up to actual repletion-point. Assuming, for convenience, that the former was actually the case, I will provisionally place *Charaxes brutus* in what I will call Grade 1. It seems likely from the refusal of *Precis cebrene* and *Neptis goochi* immediately afterwards that they at any rate did not come higher than this Grade 1, and from the eating of the *Precis* only a few minutes later that it did not come appreciably below it. With *Melanitis leda* (stimulation?) it was then eaten readily immediately after the rejection of *Neptis goochi* and *Nychitona medusa*. This gives the order:—

1. *Charaxes brutus*, *Precis cebrene*, and, perhaps, *Melanitis leda*.
2. *Neptis goochi*, *Nychitona medusa*.

The *Belenois* and *Papilio* were at any rate probably not preferred to the *Precis* and the *Melanitis*.]

Exp. 22.—May 21. Ate readily in succession five *Charaxes cithæron* and six *Charaxes candiope*, refusing a seventh (probably replete). Some of these had a wing, some were wingless. Five minutes later she accepted and ate the seventh *candiope* with apparent enjoyment, refused *Neptis saclava* without tasting, tasted and rejected *Neptis agatha*, crushed and very readily ate *Precis archesia*, tasted and rejected a *Papilio dardanus* ♂ with the usual smell somewhat strongly developed, and refused without tasting *Salamis anacardii* and *Papilio dardanus* ♀ f. *hippocoon*. All these were wingless.

Twenty minutes later I offered a wingless *Eurytela dryope*. This was at first refused without tasting, but the roller, which had possibly at first still had *Neptis* in mind, changed the latter and, having tasted the butterfly, crushed and swallowed it. Wingless *Neptis saclava* was then also tasted but rejected, while a ♂ *Catopsilia florella*, wingless, and two freshly dead (and supple) *Atella phalantha* with one wing each were well tasted and eaten, as also a *Eurytela hiarbas* (no wings) and a wingless ♂ *Leuceronia thalassina*. A wingless *Neptis agatha* was now tried, but the bird only got one antenna in its mouth as in the case of *Papilio echerioides* yesterday and then drew back in apparent suspicion and refused it, but a *Pyrameis*, with one wing, was tasted and eaten most readily. The bird now tasted and rejected a wingless *Terias senegalensis* and twice crushed and rejected with evident dislike a *Mycalesis campina* with one wing, afterwards refusing persistently to touch a *Belenois mesentina*, again with one hindwing attached. She readily, however, accepted and ate a *Pyrameis cardui*, a *Charaxes*, a *Precis cebrene*, two *Precis ceryne*, a *Melanitis leda*, and another *Pyrameis*, refusing the next *Pyrameis*, probably owing to repletion. Except the *Charaxes*, which was wingless, each of these last seven insects had one wing attached.

[Assuming, what at the time seemed likely, that *Charaxes candiope* was eaten to near repletion-point, *P. archesia* ♂ f. is also likely to have been eaten fairly near that point. *P. dardanus* ♂ was at any rate probably not liked *better* than these two. The 20-minutes' interval renders the placings of the later insects relatively to *C. candiope* more uncertain, but the following preferences seem deducible from the experiment as a whole:—

P. archesia preferred to *N. agatha* and *N. saclava*, *E. dryope* and *C. candiope*, at any rate not appreciably worse than the latter.

C. florella and perhaps *A. phalantha*, *E. hiarbas*, and *L. thalassina* preferred to *N. saclava*, and the *Leuceronia* at any rate was probably not liked less than *N. agatha*.

P. cardui, and perhaps *Charaxes*, *P. cebrene*, *P. ceryne*, *M. leda* each preferred to *T. senegalensis*, *M. campina*, *B. mesentina*, *N. saclava*, and *N. agatha*, and, if the *Pyrameis* was finally refused through repletion, probably in or near Grade 1.

P. dardanus ♂ was probably at any rate not preferred to *P. archesia*; *N. agatha* and *N. saclava* to *C. candiope*; *N. saclava* to *E. dryope*; or *N. agatha* to *L. thalassina*.

The bird's recognition and refusal of *Belenois* may be just worth commenting on. It will be remembered that the last—and that a single—example of this genus with wing attached that the bird had seen was on May 12, nine days before (readily eaten), and that previously to that she had seen none since April 10, when she

readily ate five, although five days before that again she had with the greatest readiness eaten seven in rapid succession and had doubtless then "sized it up" even if she had never met it before. She must then from April 10, with a small reminder on May 12, have retained in her mind a sufficiently clear impression of the degree of unpleasantness possessed by *Belenois*, ready to be put to use on the first occasion on which she was sufficiently replete to do without that butterfly.]

Exp. 23.—*May 22.* The bird was fed on grasshoppers till she refused to take any more. She, nevertheless, then accepted and ate, though with apparent difficulty as the result of growing repletion, four *Charaxes cithæron*, wingless, refusing the next without tasting. Ten minutes later she accepted and ate, though with obvious lack of appetite, two more *Charaxes cithæron*, refusing the next.

Five minutes later she again refused it.

Five minutes later again (*i. e.* ten minutes after probable repletion) she crushed and readily ate *Charaxes achæmenes*, refused without tasting *Precis cebrene* and *Atella phalantha* (each with one wing), took but threw away a wingless *Precis natalensis* ♂ f. She tested it well, however, and swallowed it without apparent dislike on its being reoffered. The next was refused without tasting, but a ♀ *Charaxes ethalion* was accepted and eaten. The bird then again tried and tossed aside the *Precis natalensis* ♂ f., but swallowed readily, after similarly crushing it, *Charaxes candiope*. She then refused the *Precis natalensis* without tasting, tasted and rejected a ♂ *Leuceronia thalassina* and a *Terias*, refused a wingless *Atella* without tasting, quite likely however recognizing it from its fulvous coloration, also, once more, the *Precis natalensis* ♂ f. (throughout offered without wings). A wingless *Melanitis* was, however, crushed and readily eaten, as was also a *Precis cebrene*. *Charaxes neanthes* with one wing was then crushed slightly and thrown aside, *Pinacopteryx pigea*, wingless, was refused persistently without tasting, *Precis natalensis* ♂ f. was refused and then accepted and dropped, but three *Melanitis* in succession were crushed and readily eaten, as were *Papilio dardanus* ♀ f. *hippocoon* (without perceptible smell), *Hamanumida dædalus*, and *Precis ceryne*. A second *Precis ceryne* was refused without tasting. I have never yet seen the roller so obviously replete.

All butterflies in this experiment were offered with one hindwing attached, unless otherwise stated.

[Conclusions: *C. cithæron*, judging from signs of repletion, was placed as high, probably, as any butterfly yet. *C. achæmenes* is probably in Grade 1 too, or at any rate no lower than *P. cebrene*; the *Charaxes ethalion* ♀ and *C. candiope* were preferred to *P. natalensis* ♂ f., an individual of which, however, was eaten at, or not far from, repletion-point; *M. leda* and perhaps *P. ceryne*, *P. cebrene*, *H. dædalus*, and *P. dardanus* ♀ f. *hippocoon* were also all apparently preferred to a *P. natalensis* ♂ f. as well as to *L. thalassina* ♂, *Terias*, and, probably, *Atella phalantha*. The *Melanitis* and perhaps the *Papilio*, the *Hamanumida*, and *P. ceryne* were also preferred to *P. pigea* and *Ch. neanthes*, or else to whatever these two butterflies may have been reminiscent of, and *P. cebrene* was at least not liked worse than these latter.]

Exp. 24.—*May 23.* Crushed and unhesitatingly rejected the larva of *Pyrameis*

cardui. This was early in the morning, before the bird had been supplied with food, and she was unmistakably hungry and eager.

[At this time of day, before feeding, the bird, as will be seen later, was sometimes hungry enough to eat even *Acreinæ*, so that the unacceptability to her of the *Pyrameis* larva is likely to have been very considerable.]

Later in the day (the bird had just previously been feeding on grasshoppers) she tasted and rejected *Neptis saclava*, refused without tasting *Phrissura isokani* (quite likely taken for *Mylothris*), readily ate, after crushing each, *Precis clelia*, *Pyrameis cardui*, *Precis cebrene*, a *Mycalesis safitza* (with all its wings), and a *Precis archesia* ♂ f., but rejected, after tasting it, a *Belenois mesentina*.

Three *Charaxes brutus*, two *Charaxes candiope*, and a fourth *Charaxes brutus* were now readily eaten, the last two with difficulty; the next was crushed and dropped, and on being reoffered refused without tasting. Bird apparently thoroughly replete. She now crushed slightly and threw away *Catopsilia florella* ♂, refused without tasting *Pyrameis cardui* and *Precis cebrene*, but then accepted, crushed well, and swallowed *Charaxes guderiana*, afterwards crushing and dropping *Charaxes neanthes* and refusing without tasting *Charaxes cithæron*.

Fifteen minutes later she readily accepted and ate a *Precis cebrene* and a *Catopsilia florella*, but refused without tasting a *Pyrameis*, a *Mycalesis safitza*, a *Leuceronia*, and a *Charaxes neanthes*, evidently still feeling replete.

Five minutes later she ignored *Precis cebrene* and a *Pyrameis cardui*, but accepted and swallowed, though with decided disinclination, *Catopsilia florella* and *Charaxes cithæron*, refusing the next *C. cithæron*.

I afterwards at intervals (during 20 minutes) offered her *Charaxes* and other butterflies and grasshoppers, but she was apparently thoroughly gorged and completely ignored them all as she basked in the sun with feathers ruffled out and bill open—a common habit.

[Apparent order of preference:—

- a. *P. clelia* and perhaps *1. C. guderiana.*
M. safitza and *P. 2. C. brutus* and perhaps *C. candiope*, *P. cebrene*, and
archesia ♂ f. *P. cardui.*
3. N. saclava and *P. isokani* (or whatever the latter
was taken for); *B. mesentina.*
- b. *1. C. guderiana*, } perhaps *C. cithæron.*
2. C. florella, }
3. P. cardui, *P. cebrene*, *C. neanthes*, *M. safitza*, *Leuceronia*.]

The *Pyrameis cardui* larva was probably much disliked.

Exp. 25.—Seeing that the bird was unlikely to eat more before his next pellet, I now left scattered fairly closely and thoroughly mixed on the floor of its cage three *Charaxes brutus*, three *Charaxes candiope*, three *Pyrameis cardui*, three *Precis cebrene*, one *Eurytela hiarbas*, three *Neptis saclava*, and one *Papilio lyæus*. From her experience since entering confinement the bird should have known well all these butterflies except perhaps *Eurytela*, which she had had only once. I hoped in this way to gain some confirmation by another method of her already displayed preferences.

Half an hour later two *Charaxes candiope* only had been eaten.

Half an hour later again two *Charaxes brutus* only had been eaten.

I next put in a handful of grasshoppers, etc., in great variety and two more *Charaxes brutus*. The bird descended, ate a number of the grasshoppers, and returned to her perch, having taken no notice of the butterflies.

Three hours later (evening) there remained one *Charaxes brutus*, one *Pyrameis cardui*, one *Junonia*, one *Papilio lyceus*, a number of the bird's favourite species of grasshoppers and some termites. The butterflies eaten since I last looked were two *Charaxes brutus* (two of the five had been eaten previously), one *Charaxes candiope* (two of the three had been eaten at the outset), two out of three *Pyrameis cardui*, two out of three *Precis cebrene*, the only *Eurytela hiarbas*, and all three *Neptis saclava*.

[The first butterflies eaten were four out of six large *Charaxes*, the smaller butterflies amongst which they were scattered having been apparently ignored. This might seem to merely confirm my other experiments which have always seemed to place these two species of *Charaxes* in Grade 1. Actually, however, an exceedingly important factor in determining the bird's choice is likely to have been *size*.

Against this we find that two out of nine big butterflies were left at the end, and also only two out of ten small ones. But it is possible that through stillness or position the two large butterflies left escaped the roller's observation, while some of the smaller ones were more prominent or accessible or happened to move.

Then as to relative pleasantness. Three butterflies out of fourteen that the other mode of experimentation places in or near Grade 1 were left uneaten and only one (and that the pleasantest) of the five that it places below Grade 1: 21 % against 20 %. These figures again would appear to indicate indiscriminate-ness—and "indiscriminateness" there may have been if the roller, on the occasion of any of her unwitnessed descents, had been hungry enough to eat *Neptis saclava*, the lowest-grade butterfly put down: and she obviously *had* been hungry enough. Under these circumstances *Neptis saclava* would be in a sense as acceptable to the roller as a *Precis* or *Pyrameis*, and would certainly be picked up and eaten if it caught her attention first or were more accessible.

The one definite preference apparently shown (apart from that for *Charaxes* at the commencement) was for the pleasanter grasshoppers as against *any* of the butterflies. Yet even this conclusion is not secure. Was the handful of insects put down together in a prominent mass, or was it scattered evenly through the butterflies already there? Would the roller at that moment not perhaps have descended with equal readiness and eaten as heartily had the handful been one of high-grade butterflies? Was she temporarily tired of butterflies and wanting a change through having eaten so many? Or, did she actually and usually (as was very possible) prefer the grasshoppers to the pleasantest butterflies?

The experiment, a poor one, unfortunately answers neither these questions nor any other. It was mostly unwatched, and such portions as *were* witnessed were not sufficiently fully recorded.]

Exp. 26.—May 24. Had evidently not gone down to eat recently as she was unmistakably hungry in manner. She crushed and readily ate a *Neptis agatha*, but

threw away a *Neptis saclava*. She went on to crush and eat in quick succession another *Neptis agatha*, a *Neptis saclava*, and a *Neptis goochi*, then seven more *Neptis saclava*, four *Neptis goochi*, and yet another *Neptis agatha*, also a *Belenois* and a *Leuceronia argia* ♀. All these were eaten with apparently the greatest relish. She then tasted and rejected with evident dislike *Mylothris agathina*, *Nyctemera leuconoe*, and *Danaïda chrysippus*, but readily ate a *Pyrameis cardui*, a *Precis clelia*, and a *Precis cebrene*. All the above had one hindwing attached.

I now gave her five *Charaxes brutus*, all of which were eaten with apparent relish. She then tasted and rejected *Neptis agatha* with evident dislike and refused without tasting *Neptis saclava*, each of these with one wing, afterwards tasting and rejecting, without wings, *Neptis saclava* and *Eurytela hiarbas*. She then refused *Precis cebrene*, wingless, but immediately afterwards tasted it and, evidently reassured, swallowed it at once with the greatest readiness, as also a *Pyrameis cardui*. She now tasted and rejected a one-winged *Eurytela hiarbas*, tasted suspiciously and, after a little wavering, dropped *Catopsilia florella*, but readily ate, after crushing it, a *Charaxes neanthes*, refused persistently even to taste *Terias senegalensis*, *Glutophrissa saba* ♀, and *Belenois severina*, each with one wing, hesitated considerably over taking a *Charaxes zoolina*, very possibly, I think, as a result of its whitish coloration, and finally tasted it very warily and with evident suspicion and dropped it. On my reoffering it a second and third time, she each time again went through this performance, apparently not finding enough wrong with the taste to decide her finally against the insect, yet perhaps unable to make up her mind to eat a butterfly which in appearance possibly reminded her of some Pierine that she was not hungry enough to eat.

She now readily ate a *Charaxes cithæron*, two *Charaxes candiope*, and three *Charaxes brutus*, the last two or three with decided difficulty, evidently through repletion, refused without tasting *Pyrameis cardui* and *Precis cebrene*, crushed perfunctorily and threw aside a *Precis archesia* (wingless), refused without tasting a wingless *Charaxes zoolina*, crushed and listlessly threw aside *Charaxes neanthes*, and refused without tasting *Pseudacræa lucretia*.

Now and during the next forty minutes I several times offered her the pleasanter grasshoppers and such butterflies as the large species of *Charaxes*, *Pyrameis*, and *Junonia*, but they were always refused without tasting. At about the end of that time, however, she roused herself somewhat, tasted and readily ate two *Precis cebrene* and a *Precis clelia*, tasted and rejected *Neptis saclava* and *Glutophrissa saba* ♀, but readily ate after tasting each a *Precis cebrene*, a *Pyrameis cardui*, the *Charaxes neanthes* previously refused, and *Precis archesia*, tasted and rejected *Papilio angolanus* and *Pseudacræa lucretia*, but readily ate a *Pyrameis cardui*. She then tasted and rejected a *Byblia*, readily ate a *Precis cebrene*, tasted and rejected *Acraea encedon*, but readily ate a *Pyrameis cardui* and a *Precis cebrene*.

A little later, evidently slightly hungrier, she ate readily enough, after crushing each, a *Eurytela hiarbas* and a *Neptis saclava*, then (but with some slight hesitation) a *Neptis goochi*.

[In the first part of the experiment the roller ate *Pyrameis cardui* (2), *Precis cebrene* (2), *Precis clelia*, *Charaxes brutus* (8), *C. neanthes*, *C. cithæron*, and *C. candiope* (2) after refusing to eat *Mylothris agathina*, *Nyctemera leuconoe*, and *Danaïda*

chrysippus; ate all the first *P. cardui*, *P. cebrene*, *C. brutus* (3), *C. neanthes*, *C. cithæron*, and *C. candiope* (2) after refusing *Neptis saclava*, *Neptis agatha*, and *Eurytela hiarbas*; *C. brutus* (3), *C. neanthes*, *C. cithæron* (1), and *C. candiope* (2) after refusing, waveringly, *C. florella*; and the three largest *Charaxes* (1 *cithæron*, 2 *candiope*, and 3 *brutus*) after refusing *Terias senegalensis*, *Glutophrissa saba*, *Belenois severina*, and, possibly from suspicion of its white coloration, *Charaxes zoolina*.

From the wavering nature of the *Catopsilia*'s rejection it seemed not unlikely that it too would have been eaten nearer repletion than either species of *Neptis*, the *Eurytela*, the *Mylothris*, the *Nyctemera*, or the *Danaida*. The fact that the last three species were refused no less than 17 places away from repletion (11 of these places being occupied by such bulky insects as *Charaxes brutus*, *cithæron*, and *candiope*) would seem to indicate that the roller placed them very fairly low. The great contrast in manner might be taken to suggest that *Neptis agatha*, the *Leuceronia*, and the earlier *Belenois* would have been placed higher than they, but all, I think, that can be said with any safety is that the *Leuceronia* at all events was not placed lower than the *Mylothris*, etc. It and its companions should have been reoffered after the latter's rejection.

N. agatha, *N. saclava*, and *E. hiarbas* were rejected at 9 places from repletion (the 9 including 6 large *Charaxes*), the *Catopsilia* at 7 (quite unusually low for it). The *C. neanthes* was at any rate not below the later *Belenois*, the *G. saba*, and the *Terias senegalensis*, and these three insects were refused at 6 places from repletion. The 3 large species of *Charaxes* were at any rate not below *P. cardui*, *P. cebrene*, *P. archesia*, *C. neanthes*, or any species of grasshopper that I was able to offer. The latter point is interesting in relation to experiment 25.

Last part of experiment: *P. cardui* and *P. cebrene* above the *Byblia*, *A. encedon*, *P. angolanus*, *P. lucretia*, *N. saclava*, and *G. saba*; *C. neanthes* and *P. archesia* above the two last-named insects and *P. clelia* not below them. *C. neanthes* and *P. archesia* not below *P. angolanus* or *P. lucretia**.

Exp. 27.—May 25. Had been allowed no food since a good meal, possibly three hours before, and seemed distinctly hungry. She readily ate *Neptis goochi*, refused emphatically and persistently without tasting a *Terias senegalensis*, then stretched out eagerly for *Neptis goochi*, crushed and at once swallowed it, readily ate, after crushing it, *Herpencia eriphia* and, with some hesitation, the previously-refused *Terias* (now stripped of wings), ate a *Nychitona medusa* and *Phrissura isokani* ♂ (the last with a front wing attached; all the others, unless otherwise stated, with one hindwing), then tasted and rejected *Mylothris yulei* with very evident dislike, but readily ate a *Rhopalocampta* with distinct *Amauris*-smell. The eating of the *Nychitona* and *Terias* was probably the result of immediately preceding stimulation.

I now gave her a *Charaxes brutus natalensis* and one *Charaxes candiope*, after eating which she tasted and very readily swallowed *Neptis goochi* and refused very persistently without tasting the wingless body of *Terias senegalensis*, once leaning forward and half tasting but drawing back without attempting to remove it from the forceps. She crushed, however, and readily ate *Phrissura isokani* and a

* Some of the acceptances in this experiment may have been the result of stimulation: I have made the necessary allowances for this in carrying out these results to the final list.

♀ *Papilio lyceus*. She now readily ate two *Charaxes brutus natalensis*, tried unhesitatingly and rejected *Neptis agatha*, refused persistently without tasting *Phrissura isokani*, but tried and this time ate a second *Neptis agatha*, following it up by a *Henotesia* and a *Leuceronia thalassina*.

She ate readily a *Charaxes brutus natalensis* and a *Charaxes candiope*, tasted and very promptly rejected *Neptis agatha*, refused to touch *Neptis goochi*, tasted and rejected *Phrissura isokani*, *Leuceronia thalassina*, and *Neptis goochi*, but ate, after tasting it, *Atella phalantha*. She now tasted and rejected a second *Leuceronia thalassina* ♂, tasted and ate a *Byblia*, tasted and at once rejected a *Mycalesis campina*, refusing it persistently without tasting on its being reoffered, crushed and readily ate *Eurytela dryope* and *Rhopalocampta pisistratus* (with a slight bug-like smell).

She now readily ate two *Charaxes brutus natalensis*, one *Charaxes neanthes*, one *Sarangesa*, one *Papilio lyceus*, one *Pyrameis cardui*, one *Precis cebrene*, and two *Charaxes candiope*, the second being swallowed with a little difficulty, due, I thought, to repletion. *Charaxes neanthes* was readily eaten, *Sarangesa*, *Atella phalantha*, and *Eurytela dryope* refused without tasting, *Precis cebrene* accepted, crushed, and swallowed, the *Sarangesa*, *Atella*, and *Eurytela dryope* once more refused, a *Pyrameis cardui* accepted, crushed, and eaten, the *Sarangesa*, *Atella*, and *Eurytela* refused without tasting for the third time, as also a *Lampides bætica*, but a *Rhopalocampta libeon* was tasted and readily eaten, another skipper (probably a *Gegenes*) refused without tasting, a *Melanitis leda*, offered both with wings and without, crushed each time and tossed away, a *Precis cebrene* refused for a moment, then taken, tasted, and readily swallowed, as was also a *Pyrameis*: and a *Precis clelia* and a *Precis cebrene* refused without tasting. The bird now accepted *Charaxes brutus*, played with it for a while, continually tossing it up into the air and catching it again, and finally tossed it aside, apparently replete.

[SUMMARY:—

(1) After the refusal of *M. yulei* the following were eaten: 1 *Henotesia perspicua*, 2 *C. neanthes*, 6 *C. brutus*, 4 *C. candiope*, 1 *N. goochi*, 1 *N. agatha*, 1 *A. phalantha*, 1 *Byblia* sp., 1 *E. dryope*, 3 *P. cardui*, 3 *P. cebrene*, 1 *P. isokani*, 1 *L. thalassina*, 2 *P. lyceus*, 1 *Rhopalocampta* (sp.?), 1 *R. pisistratus*, 1 *R. libeon*, 1 *Sarangesa*.

(2) After the refusal of *T. senegalensis* were eaten: all the above except 1 *C. brutus*, 1 *C. candiope*, the *N. goochi*, and the *Rhopalocampta* sp.—these not offered.

(3) After *N. agatha* (finally), *N. goochi*, *P. isokani*, and *L. thalassina* were refused, the bird ate 2 *C. neanthes*, 2 *C. brutus*, 2 *C. candiope*, 1 *A. phalantha*, 1 *Byblia* sp., 1 *E. dryope*, 3 *P. cardui*, 3 *P. cebrene*, 1 *P. lyceus*, 1 *R. pisistratus*, 1 *R. libeon*, 1 *Sarangesa*.

(4) After the refusal of the *Mycalesis campina* there were eaten the species just enumerated in (3), excepting the *Atella* and *Byblia*—but the *Mycalesis* was apparently not higher than the latter.

(5) After the refusal of the *Sarangesa*, *Atella*, and *E. dryope* the bird ate 2 *P. cardui*, 2 *P. cebrene*, 1 *R. libeon*.

(6) After the refusal of *L. bætica*, 1 *P. cebrene*, 1 *P. cardui*, and 1 *R. libeon* were eaten.

(7) After the refusal of the *Melanitis* and the *Gegenes*, 1 *P. cebrene* and 1 *Pyrameis* were eaten, each of these species and a *C. brutus* being then refused.

(8) Out of some of these placings it seems possible to extract the following grades :—

1. <i>P. cardui</i> , <i>P. cebrene</i> , <i>R. libeon</i> .	}	<i>Charaxes</i> spp., <i>Byblia</i> spp., <i>P. lycæus</i> ,	
2. <i>A. phalantha</i> , <i>E. dryope</i> , <i>Sarangesa</i> .		and <i>R. pisistratus</i> hereabouts.	
3. <i>N. agatha</i> , <i>P. isokani</i> , <i>N. thalassina</i> , <i>N. goochi</i> .			
4. <i>M. yulei</i> , <i>T. senegalensis</i> (this last not tested against <i>N. goochi</i> , than which it is at any rate apparently not higher).			
(9) <i>M. yulei</i>	refused at 32 (incl. 10 large <i>Charaxes</i>)	from repletion:	might have gone lower.
<i>T. senegalensis</i>	„ 28 („ 8 „ „)	from repletion:	eaten with hesitation at 34.
<i>N. agatha</i>	„ 19 („ 4 „ „)	from repletion:	eaten at 23.
<i>N. goochi</i>	„ 19 („ 4 „ „)	„ „ „	„ 28.
<i>L. thalassina</i>	„ 19 („ 4 „ „)	„ „ „	„ 21.
<i>P. isokani</i>	„ 19 („ 4 „ „)	„ „ „	„ 27.
<i>M. campina</i>	„ 17 („ 4 „ „)	„ „ „	: might have gone lower.
<i>Sarangesa</i>	„ 5 („ 0 „ „)	from repletion:	eaten at 11.
<i>A. phalantha</i>	„ 5 („ 0 „ „)	„ „ „	„ 18.
<i>E. dryope</i>	„ 5 („ 0 „ „)	„ „ „	„ 16.
<i>L. bætica</i>	„ 3 („ 0 „ „)	„ „ „	: might have gone lower.
<i>Melanitis</i> and } <i>Gegenes</i> }	„ 2 („ 0 „ „)	from repletion:	might have gone lower.

The above gives a rough idea of the placing, relatively to repletion-point, of some of the species used. In particular, it seems to show that *M. yulei* and *T. senegalensis* are placed very low.]

Exp. 28.—*May* 27. Refused most persistently a *Nychitona medusa*, but ate readily after crushing each an *Atella phalanthæ* and a *Lampides bætica*. She then accepted, crushed, and, after hesitation, swallowed a *Terias*, refused without tasting a wingless *Acraea esebria*, tasted and emphatically rejected *Nyctemera leuconœ* (with tomato-leaf smell), and refused persistently without tasting a *Mylothris agathina*.

She now ate readily two *Charaxes brutus* and after them, tasting each and then swallowing it without the least hesitation, *Neptis agathæ* and *Eurytela hiarbas*, tasted and rejected a *Belenois mesentina*, but readily ate, after tasting it, a *Leuceronia thalassina*. She then persistently refused a *Terias* and a *Myc. campina* without tasting them, each with one wing, ate two more large *Charaxes* and a *Leuceronia argia* and then with increasing slowness four more large *Charaxes*. The next *Charaxes* was refused through sheer repletion, as also several other butterflies including *Pyrameis cardui*, *Precis cebrene*, and *Lampides bætica*.

[SUMMARY:—*Charaxes* spp. (and perhaps *L. argia*) were preferred to *Terias* and *M. campina*, and, with *L. thalassina*, to *B. mesentina*, with *C. brutus* and

L. thalassina (and perhaps *N. agatha* and *E. hiarbas*) to *A. esebria*, *N. leuconoë*, and *M. agathina*, and with *Atella* (and perhaps *L. bætica* and *Terias*) to *N. medusa*. *A. esebria*, *N. leuconoë*, and *M. agathina* probably not above *Terias*, above *N. agatha* or *E. hiarbas*, *Terias* or *M. campina* over *L. thalassina*, or *P. cardui*, *P. cebrene*, or *L. bætica* over the large species of *Charaxes* eaten at the end.]

Exp. 29.—May 28. After a longish fast, hungry in manner. Crushed and at once ate *Terias senegalensis*, wingless. I then gave a *Mylothris agathina*. She crushed and quite evidently disliked it, but hesitated as though almost persuaded by her appetite to swallow it nevertheless, then threw it away. She then readily accepted and swallowed a *Belenois mesentina* with no sign of dislike.

Next, after eagerly eating two *Charaxes cithæron*, offered as usual in the case of the larger *Charaxes* without wings, she tasted well and at once rejected a *Terias*. There could be no doubt as to her present dislike for it.

Then, after one *Charaxes brutus* and one *Charaxes candiope*, she crushed and ate a thorax of a wingless *Phrissura isokani*, having snatched it away so that the abdomen remained in the forceps. I now offered this (the abdomen) and it was crushed and thrown away.

I then gave the bird another *Charaxes brutus natalensis* and another *Charaxes candiope* and offered her three times a wingless *Pseudacræa lucretia* (gravid ♀). It was each time thoroughly tasted and tossed away, and a ♂ with one wing was similarly crushed and rejected. The bird then tasted and rejected a *Byblia* but readily enough ate the next two. The next (a different individual from the first) was, however, rejected. She now ate readily after thorough crushing a *Papilio demodocus* with one wing, but tasted and emphatically rejected a *Mycæsis campina*, immediately afterwards readily eating a *Leuceronia thalassina* ♂ (wingless). A ♀ *Phrissura isokani* (with one wing) was now refused without tasting but finally crushed and at once swallowed.

The bird now ate two *Charaxes candiope* and then accepted, tasted, hesitated for a second over and swallowed a *Leuceronia thalassina* ♀. She then tasted and readily ate a *Eurytela dryope* with one wing, but refused without tasting a wingless *Eurytela hiarbas*, possibly suspecting it of being a *Neptis*. Finally, however, she tasted it cautiously and, with an air of reassurance, swallowed it, readily ate a *Papilio lyæus* ♂ after crushing it well, again tasted and rejected the ♀ *Pseudacræa lucretia*, but crushed and readily ate an *Atella phalantha*. A *Byblia* was now crushed and eaten, the next tasted and rejected, a third tasted and readily eaten, a fourth with a slight musk-smell crushed and rejected emphatically, and a fifth refused persistently without tasting. She then crushed and readily ate a *Melanitis leda* and a *Precis archesia* (each with one wing), also a *Hamanumida dædalus* and a *Precis ceryne*.

A *Charaxes brutus natalensis* and a *Charaxes cithæron* followed and, after them, a *Charaxes neanthes* and a *Pyrameis cardui* were eaten, both most readily. She then crushed a *Henotesia perspicua*, wavered a good deal over it, but finally threw it away and wiped her bill, and tasted and very promptly rejected *Myc. campina*.

A *Charaxes brutus natalensis* and a *Charaxes cithæron* were now once more

accepted and eaten. The roller was then twice offered a *Papilio lyæus* ♀ and each time tasted it well and rejected it, but tasted and most readily ate a *Precis archesia*, a *Hamanumida dædalus*, a *Pyrameis*, a *Precis cebrene*, and a *Sarangesa*.

She then readily ate a *Charaxes candiope*, a *Charaxes brutus*, a *Precis cebrene*, and a *Byblia*, but crushed and rejected the next *Byblia* and the ♀ *Pseudacræa lucretia*. She was, however, probably now replete, as evidenced by the fact that she persistently refused without tasting *Charaxes brutus*, *Hamanumida dædalus*, *Precis cebrene*, and *Lampides bætica*.

[SUMMARY :—

(1) After *M. agathina* was rejected the bird ate 1 *Melanitis leda*, 1 *C. neanthes*, 4 *C. cithæron*, 5 *C. brutus*, 5 *C. candiope*, 5 *Byblia*, 1 *E. dryope*, 1 *E. hiarbas*, 1 *A. phalantha*, 2 *P. cardui*, 2 *P. cebrene*, 2 *P. archesia*, 1 *P. ceryne*, 2 *H. dædalus*, 1 *B. mesentina*, 1½ *P. isokani*, 1 ♂ and 1 ♀ *L. thalassina*, 1 *P. demodocus*, 1 *P. lyæus*, and 1 *Sarangesa* (*M. agathina* rejected 40 places, including 14 large *Charaxes*, from repletion-point).

(2) After rejecting a *Terias* she ate all these less the *B. mesentina* and 2 *C. cithæron* (*Terias* rejected 37 places, including 12 large *Charaxes*, from repletion-point).

(3) After rejecting the ♂ and ♀ *P. lucretia* she ate all in list (1) except the *Belenois* and the 2 *C. cithæron* just mentioned and except 2 *C. brutus*, 2 *C. candiope*, and the *P. isokani* thorax (*P. lucretia* rejected 32 places, including 8 large *Charaxes*, from repletion-point).

(4) After rejecting *M. campina* she ate list (1) with the exceptions already mentioned and the further exceptions of 2 *Byblia* and the *P. demodocus* (= 29 places).

(5) After rejecting the last of the main lot of *Byblia*s she ate 1 *M. leda*, 1 *C. neanthes*, 2 *C. cithæron*, 3 *C. brutus*, 3 *C. candiope*, 1 *Byblia*, 2 *P. cardui*, 2 *P. cebrene*, 2 *P. archesia*, the *P. ceryne*, 2 *H. dædalus*, and the *Sarangesa* (= 21 places).

(6) After rejecting *H. perspicua* (so waveringly that she may have been nearly hungry enough for it) she ate 1 *C. cithæron*, 2 *C. brutus*, 1 *C. candiope*, 1 *P. cardui*, 2 *P. cebrene*, 1 *P. archesia*, 1 *H. dædalus*, 1 *Byblia*, and the *Sarangesa* (= 11 places).

(7) After rejecting *P. lyæus* she ate these less 1 *C. brutus* and the *C. cithæron* (= 9 places including only 2 large *Charaxes*).

(8) *Terias senegalensis* probably not liked less than *M. agathina*; *P. demodocus* than *M. campina*; *P. lyæus* than *Ps. lucretia*; the last *Byblia* eaten not less than *C. brutus*, *M. dædalus*, or *P. cebrene*. Hesitation over *L. thalassina* ♀, probably due to its *Mylothris*-like appearance.

(9) By disregarding throughout the experiment the possibility of special stimulation (such as probably caused *Byblia* to be eaten to repletion-point) one might deduce much from this experiment. Taking it into account, all that can fairly safely be said with regard to preferences is that *P. archesia* was apparently preferred to *P. lyæus*, and, with *C. brutus*, to *H. perspicua* (which on manner may have been preferred to *M. campina*); with *C. brutus* and *M. leda* to "unstimulated" *Byblia*; with *C. brutus*, *M. leda*, and *A. phalantha* to *P. lucretia*; with these three and *L. thalassina* ♂ to *M. campina*; with these four and *P. demodocus* to, again, *Byblia* and *P. lucretia*, also to *Terias* and perhaps *P. isokani*; and with these five and *B. mesentina* to *M. agathina*.]

Exp. 30.—May 29. To “place” *Pseudacræa lucretia* var. *expansa*.

After a longish fast, hungry in manner, the roller crushed and swallowed a *Mylothris agathina*, but in this case showed afterwards signs of dislike—shakings of head, etc. Evidently she was only just hungry enough to eat it.

I now gave her two *Charaxes brutus natalensis*, after which *Belenois mesentina* was tasted and rejected, but on being reoffered was swallowed rather under protest, the bird afterwards shaking its head a good deal. She then very readily and with no sign of dislike crushed and ate a *Neptis saclava* and a wingless *Pseudacræa lucretia expansa* (gravid ♀ of yesterday still alive).

She now eagerly ate two *Charaxes candiope*, afterwards tasting and rejecting *Neptis saclava*, refusing *Neptis goochi* without tasting and crushing well and rejecting *Pseudacræa lucretia expansa* with one wing. Reoffered, it was again tasted and at once rejected. *Neptis saclava* was then tasted and swallowed after a momentary hesitation. *Pseudacræa lucretia expansa* reoffered yet again was refused without tasting, but finally taken, crushed, and, after a moment's hesitation, swallowed. A *Neptis goochi* was now refused without tasting and a *Neptis saclava* crushed and rejected. A *Phrissura isokani* without smell or wing was then at first refused without tasting, finally tasted slightly and rejected, the bird wiping her bill.

She now readily ate two *Charaxes brutus natalensis*, then tasted and rejected *Eurytela hiarbas*.

I then gave her four *Charaxes natalensis* in succession. She refused the next, then crushed carelessly and dropped an *Atella phalantha*, and refused without tasting *Precis cebrene* and *Pyrameis cardui*. However, on my now placing grasshoppers in the cage she descended and ate four or five very small ones (not equivalent to two *Charaxes*) before returning to her perch satisfied.

[SUMMARY :—

(1) As to the *Pseudacræa*'s placing, it was eaten with *N. saclava* and rejected at the same point as the latter, and when the *Neptis* was eaten with disinclination it too required a little persuasion of the roller to induce her to eat it. That the hesitation here was slightly more prolonged than in the case of the *Neptis* might have been merely the result of the eating of the latter in between.

I wrote at the time “Any onlooker must have been convinced that the roller found nothing to choose between the decisive *Pseudacræa* and *Neptis saclava*.”

(2) Grades :—

1. Small grasshoppers (sp. not stated).
2. *C. brutus*.
3. *N. saclava* and *P. expansa*. } *N. goochi* tried less readily each time
4. *B. mesentina* and *M. agathina*. } than *N. saclava*.]

Exp. 31.—Later in the day, after some starvation, hungry in manner but less so than the first time.

I twice offered a wingless *Nychitona medusa* and it was each time tasted and at once most emphatically flung away. *Neptis saclava*, however, was readily accepted and eaten.

The bird then ate two *Charaxes natalensis*, tasted and rejected a *Myc. campina*, tasted and readily ate in quick succession a *Eurytela hiarbas*, a *Neptis saclava*, two *Henotesia perspicua*, and a *Myc. campina*.

She then ate two *Charaxes cithæron*, a *Myc. campina*, and another *Eurytela hiarbas*.

After two more *Charaxes* (*C. brutus*) she tasted very thoroughly, being evidently doubtful or disinclined, and finally rejected a *Mycalesis campina*, thoroughly tasted, and had nearly swallowed but once more brought up and threw away a *Neptis saclava*, refused without tasting a *Neptis agatha*, finally tasting it very slightly if at all and again refusing it. She then crushed and ate very readily a *Sarangesa*, refused at first a *Eurytela hiarbas*, quite likely taking it for a *Neptis*, but then tasted it and, apparently reassured, swallowed it without further hesitation. She then readily ate, after crushing each well, a *Papilio lyæus* ♀ and a *Papilio dardanus* ♂ (with decided bean-smell), tasted slightly and refused *Rhopalocampa forestan* (with a very strong smell—a mixture of prunes and *Amawris*) with much subsequent shaking of her head and wiping of her bill, readily ate a *Charaxes candiope*, but, evidently replete, crushed and threw away a *Charaxes brutus natalensis*, afterwards refusing *Precis cebrene*, *Sarangesa*, and *Pyrameis cardui* without tasting.

Fifteen minutes later she again refused all these butterflies and a *Charaxes candiope*.

[SUMMARY :—

(1) Rejected *N. medusa*, ate 4 *C. brutus*, 2 *C. cithæron*, 1 *C. candiope*, 2 *N. saclava*, 3 *E. hiarbas*, 3 *M. campina*, 2 *H. perspicua*, 1 *P. lyæus*, *P. dardanus* ♂, 1 *Sarangesa*.

(2) Rejected *N. saclava*, *N. agatha*, *M. campina*, ate *E. hiarbas*, *C. candiope*, *P. lyæus*, *P. dardanus* ♂, *Sarangesa*.

(3) On manner: after the last 2 *C. brutus* the rejections of *N. saclava* were less decided than that of *M. campina*. I commented at the time: "That this insect (*M. campina*) is less liked than *N. saclava*, though possibly very near it, I felt no doubt when witnessing the bird's treatment of each after the sixth *Charaxes*, when she had barely arrived at the *Neptis*-rejecting stage but emphatically rejected *Mycalesis*."

(4) Grades :—

1. *E. hiarbas*, *Sarangesa*, *C. candiope* (and perhaps *P. lyæus* and *P. dardanus* ♂).
2. *N. saclava*, on manner above.
3. *M. campina*.
4. *N. medusa*.

E. hiarbas, *N. saclava*, and *H. perspicua* were eaten after the rejection of a *Myc. campina*, and the acceptance of the latter butterfly immediately afterwards was probably due to their stimulating effect, as may have been several other acceptances which I have accordingly omitted from the table.]

The bird brought the last *Neptis* acceptance unusually close up to apparent repletion-point—probably the result of stimulation,

Exp. 32.—May 30. Very hungry. Tasted and at once emphatically rejected *Nychitona medusa* but readily ate, after tasting each, *Mylothris yulei*, *Mylothris rueppelli*, and *Mylothris agathina* ♂. She then tasted thoroughly and finally rejected *Nyctemera leuconoë* (with slight tomato-leaf smell), crushed and at once threw away a second *Nychitona medusa*, but quite readily ate a *Mylothris yulei* ♀.

She now eagerly accepted, crushed, and swallowed a *Charaxes candiope* and a *Charaxes natalensis*, and immediately afterwards a *Mylothris agathina* ♂ with very little smell. A *Mylothris yulei* ♂ with very decided sweet-brier smell was now tasted and dropped, perhaps accidentally, and eaten readily on being reoffered.

Two *Charaxes candiope* were now eagerly eaten, and immediately afterwards a *Mylothris yulei* (smelling of urine) readily.

Two *Charaxes natalensis* were now eaten. I then offered *Mylothris agathina* ♀, little or no smell. It was at first persistently refused without tasting, but finally well tasted and thrown away. The bird then readily ate, after tasting each, *Precis cebrene*, *Belenois severina* (with honey-scent), and *Neptis agatha*.

Then a *Charaxes cithaeron* and a *Charaxes natalensis*, after which *Neptis goochi* was persistently refused without tasting. On my now, however, substituting for it a *Neptis agatha* the bird tasted this waveringly and dropped it, but crushed and ate it on its being reoffered. *Neptis goochi* and *Neptis saclava* were now persistently refused without tasting, *Byblia* was tasted and dropped, *M. campina* tasted and at once hastily thrown away, *Leuceronia argia* ♀ crushed and very readily eaten, *Henotesia* (not of forest) offered without wings cautiously and suspiciously tasted and finally rejected. The bird now refused without tasting *Phrissura isokani*, but on my continuing to hold it to her it was carefully tasted and swallowed. A *Eurytela dryope* was then tasted somewhat suspiciously and dropped, but more boldly tasted on being reoffered and this time readily eaten. The bird now refused to touch *Tarucus plinius*, but tasted and ate a Satyrine of the species rejected shortly before (not the same individual). She then tasted and readily ate a *Gegenes* (yellow) and an *Atella phalantha*.

Two *Charaxes brutus* were now eaten, *Cacyreus lingens* refused persistently without tasting, *Leuceronia thalassina* ♂ well tasted and thrown away, *Catopsilia florella* ♂ at first refused without tasting but finally subjected to careful and prolonged tasting and eaten without sign of dislike. *Precis archesia* was then crushed and eaten with the greatest apparent relish, a *Gegenes* of previous species was twice well tasted and rejected, an *Atella phalantha* was crushed and readily eaten, but a *Byblia* refused without tasting, as was also a *Eurytela hiarbas*. A *Eurytela dryope* was however eaten most readily, a *Phrissura isokani* refused without tasting, a *Precis cebrene*, *Precis elgiva*, *Precis natalensis* ♂ f., *Hamanumida daedalus*, and *Charaxes neanthes* readily eaten, each after the usual crushing, and a *Byblia* (not offered before) well tasted and rejected.

An interruption of a few minutes now occurred—enough probably to make the roller slightly hungrier. After it a skipper (dark) was tasted and rejected, but a *Catopsilia florella* eaten readily, and after it in quick succession a *Leuceronia* (♂), a *Leuceronia argia* ♀, and the *Leuceronia thalassina* ♂ previously rejected, also a *Charaxes achæmenes*.

Charaxes pollux, *Charaxes cithæron*, *Pyrameis cardui*, and *Precis cebrene* were now eaten, a yellow *Gegenes* not offered before was well tasted and rejected, and *Eurytela hiarbas*, offered with the disguise of a *Pyrameis* wing in place of its own, was well tasted and rejected. None of the three rejected skippers had any appreciable smell.

Charaxes brutus natalensis, *Precis cebrene*, and *Charaxes cithæron* were now all readily eaten, and after them *Atella phalantha*, *Precis archesia*, and *Hamannumida dædalus*, each after the usual tasting.

Charaxes candiope and *Charaxes cithæron* were now eaten with difficulty, and a second *Charaxes cithæron* merely played with and finally tossed away and refused on being reoffered. The bird now refused without tasting *Precis elgiva* and *Pyrameis cardui*, but, finally changing her mind, accepted and ate the latter. *Precis cebrene* was then refused without tasting and a *Pyrameis cardui* accepted and eaten. A second *Pyrameis*, however, was persistently refused without tasting, though offered repeatedly at intervals.

[SUMMARY:—

(1) Extracts from my comments made immediately after the experiment:

“The bird started distinctly hungry and remained in excellent brisk tasting form from start to finish.

“There could be not the slightest doubt that the *Nychitonas* were far more disliked than any species of *Mylothris*. They were quite fairly tasted and then thrown away with marked disgust, whereas all three species of *Mylothris* were, up to the sixth *Charaxes*, eaten, after tasting, without the slightest hesitation. *Nyctemera* too was almost certainly liked better than *Nychitona*, being kept in the mouth much longer and not pitched away with the same emphasis. It was, however, very decidedly disliked. The rejected *Mylothris* lacked the heavy menthol-smell that so often characterizes *M. agathina* ♀, but *M. yulei* of each sex had the usual urine and sweet-brier scents, respectively, well developed. The *Belenois* (a ♂) smelt of honey (the first individual in which I have noticed this, captured by myself in the coffee-plantation) and was decidedly better liked than a ♀ *M. agathina* with almost no scent. The *Mycalesis* was quite likely less liked than the *N. agatha* or the *Byblia*, judging from the far prompter manner of its rejection . . . The *Eurytela hiarbas* offered under guise of *P. cardui* seemed to secure a perfectly genuine tasting and was probably rejected on its own merits and unconfused with *Neptis*. . .” I also recorded my impression from this and previous experiments that *N. agatha* is somewhat more readily attacked than *N. goochi*.

(2) Some grades:

Many of the acceptances were doubtless in part due to special stimulation by the preceding acceptance. Omitting these, and assuming for convenience that *L. thalassina* and *L. argia* were approximately equally liked, the order of preference would be roughly—

<i>M. yulei</i> .	1. <i>P. archesia</i> ☉ f.	} <i>E. dryope</i> .
	2. <i>C. florella</i> .	
	3. <i>L. thalassina</i> , <i>L. argia</i> .	
	4. <i>N. agatha</i> .	
<i>N. goochi</i> .	5. Perhaps <i>M. agathina</i> .	} <i>H. lingeus</i> .
	6. <i>N. leuconoë</i> (on manner).	
	7. <i>N. medusa</i> .	
		} <i>Byblia</i> .
		} <i>M. campina</i> .
		} <i>N. saclava</i> .

It is possible that even the eating of *Atella* and *E. dryope* at the end may have been influenced by that of the much-liked *P. archesia* shortly before. At any rate, *Atella* was preferred to *Gegenes*, *E. dryope* to *E. hiarbas*, *Gegenes* and *Byblia*, and *P. cebrene* to these and to *P. isokani*.

After the interruption *C. florella* was preferred to the dark skipper and *P. cardui* to (probably) the last-named, to *Gegenes*, to *E. hiarbas*, *C. cithæron*, *P. elgiva*, and (more certainly) to *P. cebrene*, and *C. brutus* to the *Gegenes*, *Eurytela*, and dark skipper.

(3) Some interesting points in the experiment were (as will appear better later) the high placing of *Atella* (stimulated?), the more consistent placing of *Byblia* as low as it has remained in subsequent experiments, the low placing of the Lycænids untasted, and the placing of the skippers. The roller seemed more inclined for *N. agatha* than for *N. goochi*, but her treatment of the former and shortly afterwards of *P. isokani* would seem to indicate that she was barely hungry enough even for them. The first rejection of *H. perspicua* was quite possibly in part due to suspicion of the not dissimilar *M. campina*—and even tasting does not always dissipate suspicion,—and it is possible that its acceptance later more accurately indicates its own standing. Similarly, the initial hesitation over *E. dryope* and *C. florella* may have been due to suspicion of something more unwelcome: thus a ♂ *L. thalassina* for which the bird was insufficiently hungry had immediately preceded the offering of the *Catopsilia*. The same might have applied to the other *Eurytela* refused without tasting, but hardly, I think, where I offered it disguised as a *Pyrameis*, and I believe the evidence in this experiment indicating that *E. hiarbas* was placed slightly below its congener to be probably reliable.]

Exp. 33.—May 31. After a fast and rather hungry in manner. Tasted and at once rejected *Nychitona medusa*, then tasted well and rejected *Acræa johnstoni* and *Nyctemera leuconoë* (with tomato-leaf smell), ate two *Charaxes cithæron* and tasted and at once rejected *Terias brigitta*, *Belenois severina*, and *Danaïda chrysippus*, and tried and rejected a *Myc. campina*, but crushed and readily ate *Eurytela hiarbas*, *Neptis goochi*, *Neptis agatha*, a small blackish skipper (probably of same species as rejected yesterday), *Neptis saclava*, two *Byblia*, and a Satyrine.

She later ate two *Charaxes brutus*, and after them a *Neptis saclava*, a *Neptis agatha*, and a *M. campina*, refused without tasting a *Terias brigitta*, crushed and swallowed rather waveringly the previous *Belenois* (now wingless), once more persistently refused the *Terias* without tasting, but readily ate a *Byblia*, ate two *Charaxes ethalion*, three *Precis cebrene*, a *Pyrameis cardui*, a *Neptis saclava*, and a

Mycalesis campina. I had no more *Charaxes*, so did not proceed with the experiment.

[SUMMARY:—

Much special stimulation probably occurred in this experiment too, and about all that can be fairly safely deduced is—

<i>E. hiarbas</i> .	{ 1. <i>Byblia</i> (on manner above <i>Belenois</i>). 2. <i>B. severina</i> .	
<i>T. brigitta</i> (not above <i>M. campina</i>).	{ 3. (Probably) <i>A. johnstoni</i> and <i>Nyctemera leuconœ</i> . 4. <i>N. medusa</i> .]	{ <i>D. chrysippus</i> . <i>M. campina</i> .

Exp. 34.—June 1. To place *Euphædra neophron*:

This experiment was carried out by my wife in my absence from home. A *Euphædra* had been captured and I was anxious to have it "placed." I left instructions to fill up to repletion-point on any food that might be available and then to offer the *Euphædra*. My wife states that the bird's ordinary food had not yet come in, and so she used meat and such butterflies as were available for the filling-up process. She offered the latter mostly as they came and without any real attempt to elicit preferences.

The bird seemed hungry and ate eagerly five or six small pieces of meat, refused without tasting a *Terias*, readily ate a *Eurytela dryope*, again refused the *Terias*, readily ate *Eurytela hiarbas*, *Neptis saclava*, and a piece of meat, but refused a second piece, once more readily ate *Eurytela hiarbas*, and refused without tasting *Neptis goochi*, but ate it on its being reoffered as also a *Leuceronia thalassina* and *Eurytela hiarbas*. She then once more refused a piece of meat, but readily ate a *Leuceronia thalassina*, a *Precis cebrene*, two *Eurytela dryope*, a *Henotesia*, a *Eurytela hiarbas*, and a *Tagiades flesus*, and again refused a piece of meat, then once more readily ate *Leuceronia thalassina*, *Eurytela dryope*, *Neptis saclava*, and a *Satyrine*, tasted well and rejected a skipper (yellowish), but once more carefully crushed it on its being reoffered and this time ate it as also a *Henotesia* and *Eurytela dryope*. A ♂ *Papilio lyceus* was, however, twice rejected after thorough tasting and the third time refused without tasting, as were also *Neptis saclava* and a *Byblia*—the bird had turned her back on being offered the *saclava*. My wife persisted in offering the *Byblia* with much coaxing, and the roller finally turned round and ate both it and the *Neptis saclava*, but persistently refused a second *saclava* without tasting. It then tasted and rejected the *Papilio lyceus* previously disapproved of, but crushed and readily ate another. The first was now picked up and once more reoffered, and still obstinately refused without tasting. *Neptis saclava* was now twice with an interval between most persistently refused, but a *Charaxes* was eaten, though a *Charaxes brutus natalensis* was then crushed and dropped. Nevertheless, the bird now examined for a second and tried, crushed, and swallowed down with apparent relish the abdomen with more than half the thorax of *Euphædra neophron* (one wing attached). *Charaxes brutus* was then accepted, crushed and dropped, and the head and smaller portion of *E. neophron*, thorax with one forewing attached, was offered. The bird leant forward evidently tempted to take it, but changed her mind and withdrew when in the very act of closing her

bill on it. On its being reoffered she ignored it. She then took but simply dropped *Papilio lyæus*, also, twice in succession, *Charaxes brutus*, ignored on re-presentation the *P. lyæus*, the *E. neophron* (head, &c.), and a *Henotesia perspicua*, ignored for some time *Atella phalantha* but finally took it listlessly in the point of her bill and dropped it, refused for a time a *Precis cebrene* but finally after a lot of coaxing accepted and ate it, accepted and thoroughly crushed the *Euphædra* head and thorax and kept it in her bill for a considerable time as she did so, but in the end threw them away uneaten, and on my wife's reoffering them accepted but tossed them aside—they had now in any case been reduced to pulp—refused *Neptis saclava*, clapping her bill and shaking her head in sign of strong unwillingness, and ignored *Papilio lyæus* and *Charaxes brutus*. A few minutes later she repeatedly refused or accepted and threw aside *Charaxes brutus*.

[SUMMARY:—

(1) Refused *Terias*, ate (up to the few minutes' interval occupied in coaxing) 5 *E. dryope*, 4 *E. hiarbas*, 3 *N. saclava*, 1 *N. goochi*, 1 *P. cebrene*, 1 *Byblia*, 3 *L. thalassina*, 1 *P. lyæus*, 2 *H. perspicua*, 1 Satyrine, 1 *Tagiades flesus*, 1 other skipper.

(2) Refused meat (sp.?), ate all the above except 1 *E. dryope*, 1 *E. hiarbas*, 1 *N. saclava*, and 1 piece of meat

(3) After the interval she refused *N. saclava*, ate *Charaxes* sp., most of *E. neophron*, and a *P. cebrene*.

(4) Grades:

L. thalassina, *E. hiarbas*, { 1. *Charaxes* sp., *E. neophron*, and probably *P. cebrene*.
E. dryope, and probably { 2. *N. saclava* (if unstimulated), yellow skipper, and,
N. goochi. on manner, a *P. lyæus*.

3. Meat and *Terias*.

(5) The roller was probably overpersuaded in the matter of the *Byblia* and *N. saclava*, for turning her back was her final and most emphatic form of refusal, reserved usually for importunity that had already become irksome. The eating of the two insects above their grade would probably have inhibited appetite and would thus account for the refusal so soon of a *Charaxes*. That the *Euphædra* was, nevertheless, then eaten showed that its first impression on the roller was a very highly favourable one, and that the bird was later evidently much tempted to eat the rest of it at a time when she ate *P. cebrene* only under persuasion suggests that she in no way regretted her previous acceptance of it. It seemed to be preferred to *Charaxes brutus*.]

Exp. 35.—June 5. Hungry, was given two very large hard Acridians (*Acridium lineatum*, Stoll), battered and ate them readily enough, and after them a wingless *Precis cebrene*, accepted equally readily a wingless *Neptis saclava*, but on tasting it at once threw it away, ate a *Charaxes brutus natalensis* and a *Charaxes candiope*, crushed and dropped an *Atella phalantha*, refused but after coaxing accepted and ate a *Precis cebrene*, refused without tasting an *Atella phalantha*, and crushed and tossed aside a second *Precis cebrene*.

[Those huge Acridians were probably very filling. Often given to this and other

birds as part of their ordinary food, they were usually eaten only when (1) the bird was hungry, or (2) I had first reduced them with a hammer. Under the latter circumstances they have been eaten by various birds up to near repletion-point, and it is probable that their great hardness and size and spiky legs are a very needed as well as a very efficient protection. Their habits are not specially procryptic.

The very prompt rejection of *Neptis saclava*, on taste, after a quite unsuspecting acceptance, is highly convincing. Preferred to it were *Charaxes brutus* and perhaps *Charaxes candiope*, also *Precis cebrene*. The last-named butterfly was apparently regarded as better worth considering than *Atella phalantha*.]

Exp. 36.—June 6. Extent of hunger uncertain; was feeding on grasshoppers and termites when I commenced the experiment. Readily ate *Precis cebrene*, two *Charaxes brutus*, a *Henotesia perspicua*, a third *Charaxes brutus* and a *Charaxes candiope*, refused, but immediately afterwards changing her mind, accepted, crushed, and readily swallowed a *Neptis saclava* and a *Mycalesis campina*, the latter with the usual chocolate smell, ate four *Charaxes brutus*, and thereafter persistently refused to touch *Neptis goochi*. *Neptis agatha* was, however, accepted, crushed, and eaten with apparent readiness, but *Neptis goochi* was once more refused without tasting. She then readily ate two *Henotesia perspicua*, a *Charaxes brutus*, and a *Charaxes candiope*, and tasted and rejected an *Ypthima*. On my reoffering it, it was again properly tasted, and this time flung to the other side of the cage. *Precis cebrene*, *Atella phalantha*, and a *Mycalesis campina* were now eaten without hesitation, but there was some delay between each of these last offerings as I had exhausted my prepared material and had to hunt up each separately in the envelopes and remove the wings.

[SUMMARY, &c.:—(1) After *N. goochi* was refused, 1 *N. agatha*, 2 *H. perspicua*, 1 *C. brutus*, 1 *C. candiope*, and 1 *P. cebrene* were eaten, the two *Charaxes* perhaps in part as the result of stimulation.

(2) After the rejection of *Ypthima*, *P. cebrene* was eaten. Whether *Atella phalantha* and (especially) *Mycalesis campina* could be safely added to the lists of "preferred" butterflies would depend entirely on the length of the delay before each was offered, quite apart from any appetizing influence that the *P. cebrene* may have exerted.

(3) *Comment at the time.*—"The roller's constant refusal of *Neptis goochi* without tasting seems significant—cf. past experiments. The *Ypthima* had the usual faint smell of lemonade."]

Exp. 37.—June 7. The bird was hungry. Not having many *Charaxes* I gave her a number of grasshoppers of many species. She then tasted and rejected *Neptis saclava*, but readily ate *Precis cebrene* and *Neptis agatha*. After eleven more small grasshoppers she readily, to my surprise, ate the *Neptis saclava*. I then gave five large grasshoppers. The bird had some difficulty in swallowing the last two, and they could be plainly seen in the back of her throat whenever she opened her bill. A *Neptis saclava* was now persistently refused without tasting, a *Pyrameis* was recognized and readily eaten, a *Byblia*, smelling slightly of civet (dark hind-wing with pearl spots), was tasted and thrown away with evident dislike, but a ♀ *Leuceronia argia* was eaten, as also a *Charaxes candiope*—the latter slowly, after

being played with for a few seconds—and a *Charaxes vologeses* was simply played with and dropped, as were also a *Precis artaxia* and *Precis cebrene*.

Five minutes later, still apparently anything but hungry, she listlessly crushed and dropped *Precis artaxia* and *Precis antilope*, seemed to wake up on being offered a *Melanitis leda*, crushed and swallowed it, and after it crushed well and swallowed with apparent relish the *Precis artaxia* reoffered. *Atella phalantha* and *Precis antilope* were refused without tasting, a *Precis cebrene* accepted and eaten, a *Eurytela hiarbas* disguised with a *Pyrameis* wing well tasted and rejected, and an actual *Pyrameis* played with for some seconds and finally swallowed. The bird then, reappetized, ate with apparent liking, after crushing each, *Precis cebrene*, *Hamanumida daedalus*, and *Melanitis leda*, rejected, after tasting it, *Eurytela dryope*, but readily ate *Precis ceryne* and *Precis antilope*. She then took with disinclination, crushed slightly, and dropped *Atella phalantha* and *Eurytela dryope*; however, she was probably in any case replete, or nearly so, for she now persistently ignored *Precis cebrene*, crushed slightly and dropped *Precis natalensis* ♂ f., and once more refused without tasting *Precis cebrene*.

Ten minutes later she again persistently ignored *Precis natalensis* ♂ f. and *Precis cebrene*.

Five minutes later she refused a *Neptis saclava*, tasted and readily ate the *Precis natalensis* ♂ f., then refused without tasting, but eventually accepted and ate, a *Precis cebrene*, and after it, with an effort (or with disinclination?), a *Leuceronia thalassina* ♀ and a *Papilio dardanus* ♀ f. *hippocoon*. She now refused without tasting an *Atella phalantha*, crushed and readily ate a *Precis clelia*, persistently refused to touch a *Neptis saclava*, crushed and this time ate an *Atella phalantha*, and then persistently ignored *Hamanumida daedalus* and a *Rhopalocampta libeon*.

Five minutes later she crushed and ate with the greatest readiness a *Catacroptera cloantha*, refused without tasting *Neptis saclava*, the previously offered *Byblia* and *Papilio angolanus*, but most readily accepted a second *Catacroptera cloantha*. She was quite disinclined to eat and after playing with it (tossing it up, &c.) for a few seconds, dropped it, but on my at once reoffering the butterfly again accepted and this time crushed and swallowed it with apparent relish. She then refused without tasting *Precis ceryne*, *Rhopalocampta libeon*, a *Gegenes*, and a dark skipper, also a *Pyrameis cardui* and a *Precis cebrene*.

Five minutes later she crushed and dropped *Precis natalensis* ♂, readily ate *Hamanumida daedalus* and the brown *Rhopalocampta*, refused obstinately without tasting the *Byblia*, tasted and emphatically rejected *Papilio angolanus*, crushed and readily ate *Charaxes vologeses*, refused without tasting *Precis natalensis* ♂ f., and ate with relish *Pyrameis cardui* and *Precis ceryne*. I now offered, each with the underside of the wing up and therefore not altogether dissimilar, *Precis clelia* and *Eurytela dryope*. The first was crushed and readily eaten, the second accepted equally readily, crushed and thrown away. A *Rhopalocampta libeon* (no smell) was readily eaten, as were also a blackish skipper, a *Gegenes*, and a *Hamanumida daedalus*. *Precis natalensis* ♂ f. was crushed and tossed aside.

Three minutes later *Melanitis leda* and a *Leuceronia thalassina* ♀ were eaten readily, but a *Sarangesa djælælæ* with a slight lemonade smell was tasted and at once rejected. On being reoffered it was refused persistently, though a *Melanitis*

was readily eaten. A *Ypthima* was now refused without tasting, as was also a *Precis natalensis* ♂ disguised with a *Melanitis* wing (incongruous, however, with the blue-black body), but a *Gegenes* without smell was eaten readily, as also a blackish skipper, though *Papilio angolanus* was refused with a shake of the head. After three or four minutes an *Ypthima* was thrice offered and each time well tasted and thrown away, two *Henotesia perspicua* were eaten readily, the *Ypthima* reoffered was tasted and again thrown away, *Eurytela dryope* was well crushed and readily eaten, and *Neptis saclava* was persistently refused without tasting.

The bird, however, was getting unmistakably hungrier, the result of slight delays between the offerings, and she crushed and without hesitation ate *Papilio angolanus*, but tasted and threw right away a *Byblia*. The *P. natalensis* ♂ f. was now taken with disinclination, crushed slightly and thrown aside (emphasis far less than with *Byblia*), though *Precis clelia*, a *Melanitis leda*, a *Henotesia perspicua*, and two *Charaxes brutus natalensis* were eaten readily. I now offered another *Henotesia*, but this was refused persistently with shakes of the head, though *Hamanumida dædalus* was eaten readily.

Five minutes later the *Henotesia* was eaten readily enough, but a second of the same species crushed and rejected; a *Pyrameis* was eaten with apparent relish, but a *Byblia* refused persistently, and two more *Henotesia*, not yet offered, were well tasted and each in turn rejected.

[ANALYSIS AND SUMMARY:—The intervals serve to divide the experiment into nine sub-experiments:—

In the first, *P. cebrene* and *P. cardui* were each preferred to *Neptis saclava*, and *L. argia* ♀ and *C. candiope* to *Byblia*. *N. agatha* may have been preferred to its congener, but the possible reappetizing influence of the immediately preceding *Pyrameis* may have brought about its acceptance, as that of the eleven grasshoppers doubtless did the acceptance of the previously refused *N. saclava*. That *C. vologeses*, *P. artaxia*, and *P. cebrene* were refused even after *C. candiope* is evidence of a feeling of repletion.

In the second sub-expt., *Melanitis leda* was preferred to *Precis artaxia* and to *Precis antilope*, and its appetizing influence probably brought about the acceptance of the first-named *Precis* but failed to secure that of *Atella*, to which (and to *Precis antilope*) *P. cebrene* was preferred. *P. cardui* was preferred to *E. hiarbas* and (unless it was its influence that secured their eating) so may have been *P. cebrene*, *H. dædalus*, and *M. leda*. To *E. dryope* was preferred *P. ceryne*, and the subsequent eating of the *Eurytela* was quite likely due to the appetizing influence of the *Precis*. Here, again, repletion intervened and, ten minutes later, caused the failure of the

Third sub-expt.

Fourth. *P. natalensis* ♂ f. preferred to *N. saclava*, as also *P. cebrene*, but it may have been some appetizing effect of the latter that caused the acceptance after it of *L. thalassina* ♀ and *P. hippocoon*, though it (and these) failed to get *Atella* eaten. The latter was liked less than *P. clelia* but better than *N. saclava*, and was either finally eaten near repletion-point or itself, by inhibitory action, caused a premature rejection of *H. dædalus* and *R. libeon*.

Fifth. Even the eating of *Catacroptera* failed to secure that of *N. saclava*, *Byblia*,

and *P. angolanus*, to all of which (and apparently at repletion-point) *Catacroptera* was preferred.

Sixth. *H. dædalus* and *P. cardui* both definitely preferred, *R. libeon*, *P. ceryne*, and *P. clelia* preferred, if their eating was not the result of a special stimulation of appetite, to *P. natalensis* ♂ f.; *C. vologeses* preferred to *Byblia* and *P. angolanus*; *R. libeon* to *E. dryope*; blackish skipper and *H. dædalus* also to *E. dryope* if not a matter of special stimulation.

Seventh. The eating of *M. leda* may have influenced that of *L. thalassina*, but *S. djelalcæ* (scented like *Ypthima*) was nevertheless refused and a second *M. leda* eaten in preference to it, while *Gegenes* was certainly preferred to *Ypthima* and to *P. natalensis* ♂ f., as was, less certainly, the blackish skipper.

Eighth. *H. perspicua* and *E. dryope* both preferred to *Ypthima* and *H. dædalus* to *Henotesia*; *P. angolanus* to *N. saclava*, *P. natalensis* (on manner) to *Byblia*; and *P. clelia* (less certainly *M. leda*, *H. perspicua*, *C. brutus*) to both.

Ninth. *Pyrameis* preferred to *Henotesia* and, on manner, *Henotesia* to *Byblia*.

SUMMARY:—It is not easy to compress these preferences into a single table, but the following attempt, to my mind, roughly represents the results of the experiment:—

<i>L. argia</i> ♀.	{	1. <i>P. clelia</i> , <i>P. ceryne</i> , <i>H. dædalus</i> , <i>P. cardui</i> , <i>C. cloantha</i> , <i>C. candiope</i> , <i>C. vologeses</i> , <i>M. leda</i> , <i>G. hottentota</i> , <i>R. libeon</i> .
		2. <i>A. phalantha</i> , <i>P. natalensis</i> ♂ f., <i>E. dryope</i> , <i>H. perspicua</i> , <i>P. angolanus</i> .
<i>S. djelalcæ</i> and <i>E. hiarbas</i> .	}	3. <i>N. saclava</i> , <i>Byblia</i> (<i>goetzii</i> ?), <i>Ypthima</i> .

M. leda was eaten in preference to *P. artaxia* and *P. antilope*, and *P. cebrene* to the latter. There is nothing to show whether the two rejected species were placed as low as *P. natalensis* or between it and *Melanitis*.

Adding now the less certain placings (those complicated by a possible raising of appetite), *H. perspicua* is placed above *P. natalensis* ♂ f. though still below Grade 1, *C. brutus* and the blackish skipper are also placed above *P. natalensis* and perhaps in Grade 1, and *N. agatha*, *L. thalassina* ♀, and *P. hippocoon* are placed above *Neptis saclava*. A doubt naturally attaches to these placings.

Comment at the time.—"The bird seemed in excellent form and, an unusual thing for her, went on eating at 5-minute intervals after repletion-point had apparently been reached."]

Exp. 38.—June 8. Very hungry indeed and ate readily, after crushing each, *Nychitona medusa* and *Acræa serena* ♂, tasted and at once rejected *Acræa caldarena*, crushed and readily ate *Acræa asema*, tasted and rejected *Acræa double-dayi*, readily ate *Nychitona medusa*, tasted and rejected a very freshly emerged *Acræa serena* ♀ and a ♀ *Acræa caldarena* (the latter more emphatically), tasted and readily ate a more rubbed ♀ *Acræa serena* with, however, plenty of juice, tasted and at once rejected each of two rather rubbed *Acræa caldarena* ♂, and twice very thoroughly tasted and doubtfully rejected *Danaïda chrysippus*, holding

the insect each time longer in her bill and crushing it more thoroughly than the *Acræas*, being evidently tempted to swallow it. She ended each time in throwing it right away.

She then eagerly ate a *Charaxes candiope* and thereafter obstinately refused to touch a *Nychitona*, tasted and rejected a rubbed *Acræa serena* ♂, an *Acræa doubledayi* ♀, twice in succession a ♀ *Mylothris agathina*, subjecting it, however, to more prolonged tasting than any of the preceding insects, tasted and very promptly rejected a ♀ *Mylothris yulei* (with stronger smell), tasted well and threw away a second and different *Mylothris agathina* ♀, and after it a ♂, readily ate a *Belenois mesentina*, refused without tasting a *Terias senegalensis* with one wing, tasted and rejected it when disguised by the removal of the wing, and once more readily ate a *Belenois mesentina*, then tasted and rejected a rubbed *Acræa serena* and a ♀ *Acræa areca*, the latter with very marked signs of dislike.

An interruption of fifteen minutes now occurred while I experimented with the kingfisher. On my return the roller crushed and rejected *Terias senegalensis*, wingless, reoffered, but with the greatest apparent relish ate seven *Neptis saclava* in rapid succession.

I then gave ten grasshoppers, after which she readily ate a *Neptis goochi* and six *Neptis saclava* but threw away the seventh, then very readily ate a *Neptis agatha*, tasted and rejected *Neptis goochi* with very marked dislike, tasted and dropped but, on its being at once reoffered, once more tasted and this time swallowed readily *Neptis saclava*, again tasted and threw away with an emphatic shake of the head *Neptis goochi*, and once again quite readily accepted and ate a *Neptis saclava*, afterwards refusing without tasting a *Neptis goochi*.

She then ate one large and two small grasshoppers, and readily ate two *Neptis saclava*.

I then gave her six small grasshoppers. After eating these she tasted and rejected a *Neptis saclava* and then persistently refused it without tasting. Three minutes later I again offered it and it was again obstinately ignored, but the bird readily ate a *Hesperia* and a *Baoris*, tasted and threw away *Lampides bætica*, but on its being reoffered tasted it well and swallowed it, then refused to touch a *Catochrysops dolorosa*, though she readily ate a ♀ *Papilio lyæus*, a ♀ *Leuceronia argia*, a *Henotesia perspicua*, a *Byblia*, and a *Neptis saclava*. There had been some slight delay between the last few offerings and the bird had once more become somewhat hungry [or appetite had come in eating].

She now ate five small scraps of meat and then, quite readily, *Precis cebrene* and *Neptis saclava*. On my now giving her two large pieces of meat (she refused the next), she refused persistently and repeatedly to have anything to do with *Neptis saclava*, but readily ate a *Melanitis leda* and a *Pyrameis*, also a *Henotesia perspicua*.

At this stage I gave her an enormous *Acridium lineatum*. This was battered and crushed and finally with difficulty swallowed. The bird now refused to touch *Neptis saclava*, readily ate *Precis cebrene*, refused without tasting *Eurytela dryope*, accepted *Leuceronia argia* ♀, held it for a long time in her bill, evidently not hungry, and finally swallowed it. She then refused, but changing her mind tasted *Precis natalensis* ♂ f., and having done so, at once proceeded to crush and swallow it, refused without tasting a *Teracolus*, crushed and ate with relish an

Atella phalantha, accepted with disinclination but ate a *Precis cebrene*, refused without tasting a *Hamanumida dædalus*, took, held for a few seconds, and finally crushed and swallowed a *Precis cebrene*, refused without tasting a *Eurytela hiarbas*, accepted and ate a *Hamanumida dædalus*, and now, probably fairly replete, refused without tasting *Atella phalantha*, *Hamanumida dædalus*, and *Precis cebrene*.

Five minutes later she again refused these three, as also a small brown grasshopper, of which she is very fond.

Half an hour later she once more refused all four.

[SUMMARY, ETC. :—(1) I quote from my previous conclusions in this experiment :—

"The rejections of *Acræa caldarena*, *doubledayi*, and *areca* were very decided and emphatic, particularly the latter. On the other hand, all the *Acræa serena*, as also the *Acræa asema*, were subjected to rather more prolonged tasting. *Danaida* was evidently not distasteful in the same sense as the *Acræas*, but the bird, probably largely as the result of some past experience, was afraid to swallow it.

"In the second stage the bird tried each *Acræa* before rejecting it, but would not touch *Nychitona medusa*, which was evidently intensely disliked. It seemed probable, too, that the less nauseous *Acræas* come in acceptability almost up to the level of *Mylothris agathina*, which was itself less disliked to-day than *Mylothris yulei*. The latter had its peculiar smell strongly developed, none of the former had.

"*Henotesia perspicua* is evidently more palatable than *Neptis saclava*.

"*Prob. Order*.—1. *Precis natalensis* ☉, *Atella phalantha*, *Hamanumida dædalus*, and *Junonia cebrene*, all eaten at the very end, are evidently exceedingly pleasant. To these might be added, *Leuceronia argia* ♀ (in preference to *Eurytela dryope*), which was once more accepted practically at repletion-point, though a *Teracolus* was refused, being confused perhaps with *Belenois*.

- | | |
|--|--|
| " 2. <i>Henotesia perspicua</i> .
3. <i>Neptis agatha</i> .
4. <i>Neptis saclava</i> .
5. <i>Neptis goochi</i> .
6. <i>Belenois mesentina</i> .
7. <i>Terias senegalensis</i> .
8. <i>Mylothris agathina</i> . | 9. (<i>Mylothris yulei</i> ?)
10. <i>Acræa serena</i> and <i>asema</i> .
11. (<i>Nychitona</i> ? and <i>Danaida chrysippus</i> ?)
12. <i>Acræa doubledayi</i> and <i>Acræa caldarena</i> .
13. <i>Acræa areca</i> ." |
|--|--|

(2) Revising, I would not go so far, although I have reason to know that the above list does represent the roller's usual preferences. The following list only, I think, can be really at all justified from the first section of the experiment and the other lists that I shall give from the remainder of it:—

- | |
|---|
| (a) 1. <i>Belenois mesentina</i> .
<i>T. senegalensis</i> . { 2. <i>M. agathina</i> ♂ & ♀.
{ 3. <i>Danaida chrysippus</i> , probably (on taste, not necessarily after-effect).
<i>M. yulei</i> ♀. { 4. <i>Nychitona medusa</i> , <i>Acræa asema</i> , <i>A. serena</i> (rubbed preferred to fresh).
{ 5. <i>A. caldarena</i> , <i>A. doubledayi</i> , probably (on manner as against <i>A. serena</i>), <i>A. areca</i> ♀. |
|---|

- (β) 1. *N. agatha*, *Hesperia* sp., *M. leda*, *P. cebrene*, and probably *P. lyceus*, *A. phalantha*, *L. argia* ♀, and *P. natalensis* ♂ f.
 2. *N. saclava*.
 3. *N. goochi*, *T. senegalensis*. { Probably *C. dolorosa* and possibly *L. batika*.
- (γ) 1. *P. cebrene*.
 2. *H. dædalus*. } *L. argia* ♀, *P. natalensis* ♂ f., *A. phalantha*.
 3. *Eurytela dryope* and probably *hiarbas* (latter, at any rate, below *dædalus*).

The bird's reconsiderations of *N. goochi* and *N. saclava* show how risky it would be in this experiment to include in the highest grades *Henotesia* and the other insects the acceptance of which might have been the result of special stimulation.]

Exp. 39.—*June 9.* Very hungry after a fast of several hours. Tasted and rejected *Danaïda chrysippus*, *Amauris lobengula*, and *Acraea areca*, and refused without tasting *Acraea caldarena*, *Acraea serena*, and *Acraea cabira*. I next offered *Mylothris agathina* (a gravid ♂), with unusually strong menthol scent. It was crushed and readily eaten, and *Acraea cabira* was then crushed and readily swallowed, as also a ♂ *Acraea serena*, rather rubbed. *Acraea caldarena* ♂ was crushed and at once rejected, a white *Acraea esebria* was thoroughly tasted and swallowed, an *Acraea doubledayi* was tasted and rejected, as was also *Acraea natalica*. *Nyctemera leuconœ* ♀ was now readily eaten, a buff *Acraea esebria* tasted and swallowed after momentary hesitation, a freshly-emerged *Acraea serena* crushed and eaten, but *Acraea areca* ♂ rejected with intense disgust. Another fresh-looking *Acraea serena* was crushed and eaten, but *Danaïda chrysippus* and *Amauris lobengula* tasted and rejected.

Five minutes later the bird was sitting with feathers ruffled, possibly suffering some discomfort from the *Acraeas* eaten, possibly not. She tasted and rejected a bright-looking *Acraea serena* and a black-and-red *Acraea esebria* ♀ (gravid), crushed and readily ate *Mylothris agathina* ♂ (with a decided smell, less strong, however, than that of the ♀ accepted earlier), tasted and rejected *Acraea serena* and black-and-red *Acraea esebria*, refused obstinately without tasting *Nychitona medusa*, but tasted and readily ate *Nyctemera leuconœ* ♀ and a *Terias (brigitta?)*.

After a short interval she refused without tasting *Acraea serena*, crushed well and ate *Acraea esebria* (red-and-black ♀), refused without tasting *Acraea serena*, tasted and rejected emphatically *Nychitona medusa*, tasted very thoroughly and ended by rejecting an *Acraea serena*, disguised slightly (to secure its tasting) by being offered with a forewing instead of the usual hindwing, ate a few grasshoppers, then tasted and rejected *Belenois mesentina* and *Terias desjardinsii* (?), ate a few more grasshoppers, refused without tasting *Neptis saclava*, *Neptis goochi*, a *Byblia*, and a *Hamanumida dædalus*, but evidently recognized and at once stretched out eagerly for a *Catacroptera cloantha*, which she ate with apparent relish. She then accepted, crushed, and readily ate *Hamanumida dædalus*, *Atella phalantha*, and a *Byblia* (dark hindwing, no trace of smell), twice tasted cautiously and rejected a *Teracolus*, tasted and threw right away a *Neptis saclava*, and then refused without tasting but shortly afterwards accepted and ate a *Henotesia perspicua*.

[SUMMARY, ETC.:—1. *Note at the time.* "The *Catacroptera* was evidently very

greatly liked. *Henotesia perspicua* was liked better than *Neptis saclava* and the *Teracolus*.

"The *Acræa areca* was discarded with a greater show of disgust than either Danaine, probably simply because the bird got a good dose of the bitter fluid in her bill.

"*Acræa natalica*—a rubbed specimen and probably without a great store of liquid (it was exuding some, however)—was rejected promptly, but without special fuss, treated, in fact, like *Acræa caldarena* and *doubledayi*. There could be no doubt as to these two being very decidedly more distasteful than even fresh *Acræa serena*. I had also little doubt, taking the bird's manner as an indication, that the latter was less liked than *Acræa esebria* and still less, probably, than *Acræa cabira*. *Nyctemera* and *Mylothris agathina* (an unusually strong-smelling ♀) were less objected to than any of the above. *Nychitona* I believe to come between *Acræa caldarena* and *Acræa serena* (cf., too, yesterday's experiment). The *Amauris lobengula* had an unusually slight smell, the ♂ *Mylothris* about the average smell for a ♂ of this species. All the *Danaida* used to-day had just the average amount of smell. None of them was quite without, but none possessed the just distinguishable *Amauris* smell that one occasionally finds in this species. All the butterflies used, except *Nychitona*, had been captured by myself, so that the rubbed condition of the wings was, when present, due to natural wear and tear and not to native handling."

2. Order of preference:—

- (α) 1. *M. agathina* ♂ & ♀, *N. leuconoë*, *Terias*.
 2. *A. esebria*. } *A. cabira*.
 3. *A. serena*. }
- N. medusa*. }
D. chrysippus. } 4. *A. caldarena*, *A. doubledayi*, *A. natalica* (rubbed).
A. lobengula. } 5. *A. areca*.
- (β) 1. *C. cloantha*.
 2. *N. saclava*, *N. goochi*, *Byblia*, *H. daedalus*, *B. mesentina*,
 T. desjardinsii, *A. esebria*, &c., &c.
- (γ) 1. *H. perspicua*.
 2. *N. saclava* and *Teracolus*.]

Exp. 40.—June 10. Very hungry indeed—12 noon, and except for termites had received nothing since 6 P.M. last night.

Tasted and rejected *Danaida chrysippus* and *Amauris lobengula* (without very much smell: the *Danaida* was normal in this respect), tasted and at once rejected a fresh-looking *Acræa caldarena*, crushed and readily ate *Acræa serena*, crushed and rejected with special disgust *Acræa* sp. inc., crushed thoroughly, holding it for some time as she did so, an *Acræa doubledayi* ♂, probably not very lately emerged, and finally rejected it.

Half an hour later, no food meantime, she crushed and readily ate a ♀ *Danaida chrysippus*, tasted and rejected with disgust a strongly-smelling *Amauris lobengula*, just captured, crushed and ate without hesitation a ♂ *Danaida chrysippus*, refused

with shakes of the head but finally tasted well and rejected with marked dislike a second freshly-captured *Amauris lobengula* with decided smell, afterwards shaking her head violently, tasted and rejected in turn *Acræa doubledayi* ♂, *Acræa natalica*, and *Acræa* sp. inc., also *Acræa serena*, but ate after crushing it, with apparently the greatest readiness, *Danaïda chrysippus*.

Half an hour later she tasted and rejected *Acræa doubledayi* ♂, *Acræa natalica*, and *Acræa* sp. inc., refused with what looked like horror *Danaïda chrysippus* but finally cautiously tasted and rejected it, refused *Amauris lobengula* but then accepted, crushed and dashed it away with the greatest show of disgust.

I twice during the next thirty or forty minutes, no food meantime, offered again the *Danaïda chrysippus*, and it was each time obstinately refused without tasting, as it also was late in the afternoon after a further period of starvation. *Amauris lobengula* was similarly treated.

[SUMMARY, ETC.:—1. *Note at the time*. “I purposely carried out this *Danaïda* experiment on the roller and kingfisher on much the same lines, and the results were very similar in each case to those obtained already from other birds.

“*Danaïda* here, as there, appeared to be not only less obviously unpleasant than *Amauris* but even perhaps than any *Acræa*, but its after-effects, if eaten out of place, are quite probably villainous, whether worse than those of *Amauris* it is impossible to say, but it was refused even after a further period of starvation. *Amauris* was detested by both birds, and in point of obvious unpleasantness is quite likely as bad as even *Acræa areca*.”

2. *Order indicated* :—

1. *D. chrysippus* and *A. serena* (each, at different times, eaten in preference to the other).
2. *A. doubledayi* ♂, “without a good supply of fluid.”
3. *A. caldarena*, “fresh ♂, rejected with greater decision than” 2.
4. *A. areca*, highly spotted, “rejected with greater fuss than” 3, “*A. lobengula*.”]

Exp. 41.—*June 12.* Had fed well on grasshoppers, &c., and retired once more to her perch. I gave her a very large wood-boring larva, probably that of *Anthores leuconotus*, equal in weight to perhaps four *Charaxes*. It was run several times through her bill and swallowed with apparent relish.

She then refused without tasting a *Terias* and a *Neptis saclava*, but readily accepted, crushed, and swallowed a *Hamanumida dædalus*, tasted and rejected a *Mycalesis campina* with evident dislike, readily ate after crushing them a *Leuceronia* and a *Papilio lyceus*, hesitated to accept but after tasting readily swallowed a *Henotesia perspicua*, crushed and readily ate a ♂ *Phrissura isokani*, tasted well and rejected a dark-coloured *Byblia*, refused obstinately with shakes of the head a *Mycalesis campina*, but ate with evident relish a *Precis natalensis* ♂ f., ate readily a second big longicorn larva, crushed and tossed away *Leuceronia argia* ♂, refused without tasting *Papilio dardanus* ♂, readily ate after crushing it *Precis clelia*, refused without tasting *Leuceronia argia*, but crushed and ate with apparent enjoyment *Precis archesia* and *Precis natalensis* ♂ f., refused without

tasting *Leuceronia argia*, *Papilio dardanus* ♂, and *Eurytela dryope*, but crushed and readily ate a *Charaxes neanthes*, a *Melanitis leda*, and a *Rhopalocampta libeon* (no smell), also a *Charaxes vologeses*, the latter after a little delay, the bird being no longer hungry. She then merely played with *Charaxes pollux*, repeatedly tossing it up and catching it again and ended by dropping it, afterwards refusing *Pyrameis cardui* and *Precis cebrene*.

Ten minutes later she crushed and tossed away a ♀ *Leuceronia argia*, crushed similarly and threw right away a *Papilio dardanus* ♂, and accepted the previously-offered *Charaxes pollux* and a *Melanitis leda*, playing with each for a few seconds before finally swallowing it. She then refused without tasting, but on its being reoffered accepted, crushed, and tossed aside a *Rhopalocampta libeon* (no smell) and refused without tasting *Eurytela dryope*, *Byblia* (the dark individual previously rejected), *Pyrameis cardui*, and *Precis cebrene*.

Five minutes later she tasted and rejected *Papilio dardanus* ♂, readily ate a *Pyrameis cardui*, tasted well and rejected a light-coloured *Byblia*, crushed and readily ate a *Hamanumida dædalus* and a *Melanitis leda*, tasted and rejected a (forest?) *Mycæsis campina*, also *Henotesia*, tasted and readily ate *Precis cebrene*, *Precis elgiva*, and two *Charaxes neanthes*, then played with and finally swallowed a *Charaxes achæmenes*.

I was here interrupted for some minutes. On my return I offered *Precis natalensis* ♂ f., which was readily eaten, but the bird had evidently become hungrier, for she now crushed and at once swallowed the *Leuceronia argia* ♀ already rejected and a *Papilio lyæus*.

I now gave her two *Charaxes brutus*, after which she refused without tasting a *Leuceronia thalassina* ♀, tasted and rejected *Neptis agatha*, but accepted, crushed well, and swallowed a *Rhopalocampta libeon* with a slight Pentatomid-like smell.

[SUMMARY:—Placing in Grade 1 not only the species for which a special preference as against the next grade was shown but also those eaten or dallied with close to apparent repletion-point, we have:—

1. *R. libeon*, *C. vologeses*, *C. pollux*, *M. leda*, *C. neanthes*, *C. achæmenes*,
P. clelia, *P. archesia*, *P. cebrene* (perhaps *P. natalensis*, *P. cardui*,
H. dædalus).
2. *Leuceronia argia* and *thalassina*.
3. *Terias*, *N. saclava*, *M. campina*, and probably *Byblia*. }
P. dardanus,
E. dryope,
N. agatha.

P. lyæus, *H. perspicua*, and *P. elgiva* might all be inserted above Grade 3 were it not for the possibility that they were eaten after special stimulation.]

Exp. 42.—June 14. Moderately hungry; refused without tasting *Danaïda chrysippus*, *Acraea caldarena*, and *Acraea serena*, and a few minutes later tasted and rejected *Acraea asema*, ate readily *Mylothris agathina* ♂ and *Nyctemera leuconœ*, but tasted and rejected a small *Acraea* (*doubledayi*?).

Twenty minutes later she tasted and rejected a wingless *Danaïda*, refused without tasting *Acraea caldarena* and *Acraea serena*, but at once distinguished *Byblia* from the latter, seizing, crushing, and swallowing it.

Exp. 46.—*June 21.* Hungry; crushed and ate a *Terias* (brown underside), refused obstinately without tasting and with shakes of the head *Acræa serena*, tasted and rejected *Mylothris agathina*, crushed very thoroughly, evidently wavering, and finally threw away a *Terias* of the same species.

She then readily ate five good-sized grasshoppers, refused without tasting an *Ypthima*, but on my reoffering it tasted it well and rejected it. She then refused without tasting a rather rubbed *Neptis saclava*, recognized and eagerly seized and ate a *Pyrameis cardui*, afterwards accepting, crushing, and eating without hesitation a *Neptis agatha*. On my now again offering an *Ypthima* the bird refused it without tasting, shaking her head vigorously and finally striking it out of the forceps with the side of her bill. She then, however, readily accepted and ate the *Neptis saclava*.

I then gave her a large number of grasshoppers—fed her, in fact, till she obstinately refused to eat any more, even of her apparent favourites. Nevertheless, she now readily accepted and ate not only *Hamanumida dædalus* but a *Leuceronia*, afterwards eating a *Precis cebrene* but refusing without tasting a *Neptis agatha*. On my now pressing this on her, she tasted and rejected it, refused obstinately without tasting a skipper and *Lampides bætica*, but readily ate a *Pyrameis cardui*.

I now gave her three *Charaxes brutus* and two *Charaxes candiope*. She ate them with increasing slowness and held the last *candiope* for a long time in her bill before finally swallowing it; quite evidently she was almost replete. I now offered a brown *Crenis*. She at first refused it without tasting, but on my continuing to proffer it she accepted, crushed, and ate with evident liking not only it but a *Precis antilope* ♂ f. and a *Precis madagascariensis*.

The roller now accepted and with marked disinclination and after prolonged crushing ate a *Charaxes brutus*, held for some time a *Charaxes candiope* and after it a *Charaxes ethalion* as though loath to drop such tit-bits but too full to eat them, and finally did crush and eat each. A *Precis madagascariensis* was then more quickly crushed and eaten, and after an interval of three or four minutes a *Charaxes vologeses* was well crushed and swallowed. It was evident, however, that the bird had difficulty in getting it down, and a *Charaxes brutus* was now persistently refused without tasting.

[SUMMARY :—

- | | |
|--------------------|--|
| | 1. <i>P. cardui</i> , <i>H. dædalus</i> . |
| <i>N. agatha</i> , | 2. <i>N. saclava</i> , favourite grasshoppers. |
| Skipper, | 3. <i>Ypthima</i> and <i>T. brigitta</i> . |
| <i>L. bætica</i> . | 4. <i>M. agathina</i> : this possibly, on manner, above. |
| | 5. <i>A. serena</i> . |

The *Leuceronia*, *P. cebrene*, and *N. agatha* might also be placed above *N. saclava* and the *Crenis*, *C. ethalion*, and *P. antilope* go into Grade 1 were it not for the possibility that their eating was the result of special stimulation. The butterflies eaten right at obvious repletion-point (*C. brutus*, *C. candiope*, *C. vologeses*, and *P. madagascariensis*) may, I think, in spite of a similar objection, be placed with some confidence in Grade 1. The low placing of favourite grasshoppers was

probably—as in nearly every experiment—the result of having eaten so many. Had better flies been used for “filling up,” it is probable that the favourite grasshoppers would have been taken in preference to the favourite butterflies.]

Exp. 47.—*June 22.* Early in the day, before being fed, very hungry, had refused without tasting *Acræa serena* and *Acræa asema*, also *Danaïda chrysippus*—a testimony to their very low grade.

She now, considerably less hungry, refused without tasting and with shakes of the head *Acræa serena*; refused, then tasted very slightly and with the greatest weariness and threw aside a *Danaïda chrysippus*, refused without tasting a *Terias*, but tasted and readily ate an *Ypthima*.

I now gave her three migratory locusts, after which she obstinately refused to touch either *Lampides bætica* or an *Ypthima*. I therefore gave her an enormous mixed feed of migratory locusts, various grasshoppers, crickets, etc., and termites, and when she was thoroughly replete and would touch no more of any of them I offered her a *Charaxes neanthes*. Either through sheer repletion or from suspicion of the fulvous wing-colour (reminiscent of *Atella*?) she would not touch it, but a few seconds later was tempted by a *Pyrameis*, which she ate. I then offered *Precis ceryne* ♂ f. The bird at first refused it, but as I continued to hold it to her, tasted it slightly and, evidently attracted, took it, crushed it thoroughly and swallowed it, and directly after tasted well and readily swallowed a *Charaxes neanthes*. I now offered an *Ypthima* which she took and tasted, but at once threw away with marked dislike, wiping her bill vigorously on the perch.

[SUMMARY :—

1. *P. cardui* (possibly *P. ceryne* and *C. neanthes*).
2. Favourite grasshoppers, crickets, migratory locusts, termites, and *C. neanthes* (or *A. phalantha* if the *neanthes* was mistaken for this).
- L. bætica*. { 3. *Ypthima*.
- { 4. *Terias*, *A. serena*, *A. asema*, *D. chrysippus*.]

Exp. 48.—*June 23.* Hungry; refused obstinately without tasting *Acræa serena*; refused, then tasted in a very gingerly way and rejected *Mylothris rueppelli* and *Mylothris yulei*; tasted rather better, then rejected *Nyctemera leuconoë*.

[Possibly, on manner, we get :—

1. *N. leuconoë*.
2. *M. rueppelli* and *yulei*.
3. *A. serena*.

But this is, at best, doubtful. At any rate, all were obviously very low-grade.]

Exp. 49.—*June 24.* Moderately hungry at the start. I gave her all the meat she would eat (two smallish lumps) and then by hand a number of various grasshoppers until she at last obstinately refused to touch any more. I waited five minutes and again offered grasshoppers, but the bird held the first in its bill a considerable time before swallowing it and then refused all others. I next offered

a *Neptis saclava*. This was refused without tasting with shakes of the head, but a *Pyrameis* was accepted and eaten, a small *Sarangesa* was refused persistently without tasting, and an *Ypthima* tasted and at once emphatically rejected with much head-shaking. The bird then tasted and at once rejected a dark *Byblia* without, however, marked signs of dislike, crushed very thoroughly *Leuceronia thalassina* ♂ and ended by rejecting it, again crushing and rejecting it on its being reoffered; refused without tasting *Pinacopteryx pigea*, ate, though obviously without appetite, *Pyrameis cardui* and *Precis cebrene*, tasted slightly and threw away a *Lampides bætica*, crushed a small *Hesperia* in the point of her bill and dropped it (it had, like *Rhopalocampta*, a bug-like smell), and then refused a *Pyrameis*, though I did my level best to coax her into taking it. There could be no doubt of her repletion. I now offered *Salamis anacardii* with forewing attached. The bird at first hesitated, then bent forward, tasted and, obviously liking it immensely, crushed it up and swallowed it. The large wing caused a little delay by sticking in the gullet, but after one or two efforts it was completely swallowed, the bird all the time showing no sign of any feeling other than relish. She now listlessly took and dropped a *Pyrameis cardui*, but ate it on its being reoffered and persistently refused the next.

Ten minutes later she refused without tasting a *Mycalesis*, *Melanitis leda*, and a *Leuceronia thalassina*.

[SUMMARY :—

1. *Salamis anacardii*.
 2. *P. cardui* (*L. bætica* and the *Hesperia* here or lower).
 3. *L. thalassina* ♂.
 4. Grasshoppers. { *N. saclava*, *Ypthima*, and *Byblia* (also the
 5. Meat (sp.?). { *Sarangesa* and *Pinacopteryx*, if these were
- not mistaken, as is likely, for something else).]

Exp. 50.—*June 25.* Hungry; refused but, changing her mind, crushed very thoroughly, played with by throwing it up into the air and catching it again several times, *Mylothris agathina* ♀ with scent of medium strength, and ended by throwing it away.

She now refused without tasting both it and *Mylothris yulei*, but accepted readily, crushed and swallowed a *Belenois severina*, and refused without tasting but, on my continuing to proffer it, took, tasted and threw away a *Terias*.

I now gave her four medium-sized grasshoppers, after which she persistently refused *Neptis goochi*, tasted slightly and rejected *Neptis saclava*, refused without tasting a dark *Byblia*, but readily accepted and ate a *Precis cebrene*. She now tasted the *Byblia* and rejected it with unmistakable dislike and obstinately refused to touch a small *Pinacopteryx*, with orange base to forewings. She tasted, however, and readily ate a ♀ *Leuceronia argia*, but again refused the *Pinacopteryx* (front wing attached), mistaking it probably for a *Mylothris yulei*. After this she tasted but at once rejected a *Phrissura isokani*, and refused but tasted and then readily ate a *Lampides bætica*.

Fifteen minutes later (no food meantime) she tasted very thoroughly and

ate a large *Mycalesis*, refused for some time but finally tasted and swallowed a *Henotesia perspicua*, again refused but eventually tasted and ate an *Ypthima*. But she refused persistently to have anything to do with the next, tasted and rejected *Neptis saclava*, refused without tasting but finally tasted and pitched away an *Ypthima*, and obstinately refused the next without tasting. She now refused without tasting two small *Pinacopteryx* (one white, the other orange-based).

Ten minutes later she accepted the white *Pinacopteryx* (small), crushed it very thoroughly and rejected it, but readily ate *Neptis saclava*, then refused persistently and emphatically with shakes of the head a *Terias*. *Phrissura isokani* ♂, wingless, was now tasted and rejected.

[SUMMARY, ETC.:—(1) *Note at the time*: “The bird was distinctly suspicious of the small dark brown *Henotesia perspicua*, no doubt confusing it with *Mycalesis campina* and *Ypthima*. Immediately afterwards she was reassured (or so it appeared) by the comparative palatability of the *Henotesia* (or else appetized by it) into eating what she had probably wished to avoid—*Ypthima* itself.”

(2) *Grades*:—

- (a) 1. *L. bætica*, *L. argia*, and probably *P. cebrene*.
 2. *N. saclava*.
 3. *Pinacopteryx* sp. } *Byblia*, *P. isokani*, *N. goochi*.
- (b) 1. *Belenois severina*.
 2. *M. agathina* ♀, *M. yulei*, *Terias*.]

Exp. 51.—*June 26.* To place *Pseudacræa trimeni*. I found the roller hungry and gave her a full feed of meat, various grasshoppers, and a large beetle-grub, followed by more grasshoppers. She finally refused to touch anything more. Five minutes later she consented to eat two more small grasshoppers but with complete disinclination, and refused to touch another, though various species were offered. She now refused without tasting a *Precis cebrene*, tasted very slightly and dropped *Tagiades fesus*, crushed well and, after a little delay, the result of repletion, ate a *Pyrameis*, crushed and readily ate a *Macroglossa trochilus*, evidently liking it. She now ate, though again with disinclination, two grasshoppers of a very favourite species (previously refused) and after them readily enough another *Pyrameis*. She now refused without tasting a *Pseudacræa trimeni* with, as usual, one wing attached, but, tempted by its violent movements, accepted it, crushed its thorax thrice, and then dropped it. She then refused without tasting *Papilio lyæus* ♀, *Neptis saclava*, and *Precis cebrene*, and crushed very slightly and dropped *Pyrameis cardui*.

The *Pseudacræa* was still alive, but unlikely to survive its injuries for long.

Ten minutes later the bird crushed and dropped a *Pyrameis*, and refused without tasting a *Gegenes*.

Ten minutes later she again crushed and dropped a *Pyrameis*, but on my reoffering it ate it readily enough, refusing, however, without tasting a *Precis cebrene* and a *Pseudacræa trimeni*.

Fifteen minutes later she readily accepted and ate *Hamanumida dædalus*, obviously recognizing it, persistently refused a ♂ *Leuceronia thalassina*, and then refused but, suddenly changing her mind, accepted and readily ate a *Precis cebrene*. She now refused without tasting *Pseudacræa trimeni*, tasted and rejected *Tagiades fesus*, and refused with many shakes of the head *Neptis saclava* and a *Mycalesis campina*, as also with less demonstration *Leuceronia thalassina* ♂, *Papilio lyæus* ♀, and *Pseudacræa trimeni* ♀.

[SUMMARY :—

1. *P. cardui* (*Macroglossa trochilus* less certainly here).
2. *P. cebrene*.
3. *L. thalassina* ♂. } *Tagiades fesus*.
4. *N. saclava* and *M. campina* refused with more demonstration than *L. thalassina* ♂, *P. lyæus* ♀, and *Pseudacræa trimeni* ♀, but it would be unsafe to rely too much on this.]

Exp. 52.—June 27. To place *Pseudacræa trimeni*. Had retired to her perch after a big feed of various grasshoppers, termites, &c.; replete. She refused, then leant forward, tasted and rejected in turn *Neptis saclava* and *Neptis agatha*, refused absolutely without tasting *Phrissura isokani*, *Mycalesis campina*, and *Henotesia perspicua*, but fairly readily accepted and ate a *Pyrameis*. She now crushed well and threw away a *Leuceronia thalassina* ♂ and again ate a *Pyrameis*, crushed well and tossed away a *Papilio lyæus* ♀, and once more, though with disinclination, ate a *Pyrameis*. She then twice, with a short interval between, refused with shakes of the head yesterday's *Pseudacræa trimeni* ♀, which was still alive; refused but, on tasting, changed her mind and with a surprising show of relish, considering her treatment of the other pleasanter species, ate two *Precis natalensis* ♂ f., the second without the slightest hesitation in acceptance. She now refused a *Pyrameis* without tasting, crushed and ate with an air of disinclination a *Precis cebrene*, and then readily ate a *Precis natalensis* ♂ f. The next *Precis cebrene* was refused persistently without tasting.

Fifteen minutes later she refused without tasting *Papilio lyæus*, *Leuceronia thalassina*, and *Pseudacræa trimeni*, readily ate a *Pyrameis* and refused without tasting *Neptis saclava*.

[SUMMARY :—(1) *Grades* :—

1. *P. cebrene*.
2. *P. cardui* and probably *P. natalensis* ♂ f. (I draw no inference, however, from its last acceptance as this immediately succeeded that of a *P. cebrene*).
3. *L. thalassina* ♂, *P. lyæus* ♀, *Ps. trimeni*, *N. saclava*, *N. agatha*, *P. isokani*, *M. campina*, and, if not through mistake (as it probably was), *H. perspicua*.

(2) *Note at the time* : "The *Leuceronia* was practically killed by its tasting, the *Papilio lyæus* not, but it was disabled and would certainly not recover from its injuries."

Exp. 53.—To place *Pseudacraea*. Later in the day, the bird being once more somewhat hungry, I gave it four grasshoppers and a *Neptis saclava*, all of which were readily eaten. After five more small grasshoppers, she obstinately refused without tasting *Ypthima*, *Neptis saclava*, and *Neptis agatha*, but evidently not recognizing as a *Neptis* a *Neptis swynnertoni*, which I now offered with all its wings, at once seized on it, but on tasting it threw it hastily away. She now ate a small grasshopper, tasted and rejected in turn *Pseudacraea lucretia*, *Papilio lyceus*, and *Pseudacraea trimeni*, readily accepted and ate *Precis cebrene*, refused a *Precis natalensis* ☉, but then, as though struck by an idea, suddenly leant forward, tasted it cautiously, and at once crushed and swallowed it.

After a considerable interval to allow her to become hungry once more (for the rejection of *Papilio lyceus* had shown her to be too nearly replete), I again offered *Neptis saclava*. It was refused without tasting, but a ♂ *Leuceronia thalassina* was well crushed and readily eaten, the *Pseudacraea trimeni* was refused without tasting, a *Henotesia perspicua* was well tasted and thrown away, and a *Mycalasis campina* was refused without tasting.

The bird now at first refused, but, changing her mind, tasted, crushed, and at once swallowed *Neptis agatha*, and then, with a great shake of her feathers, roused herself from her previous listless condition and, buckling energetically to the fray, crushed and ate in quick succession *Neptis saclava*, *Ypthima*, *Henotesia perspicua*, *Mycalasis campina*, and *Belenois mesentina*, but rejected with marked disgust *Mylothris agathina* and *Mylothris yulei*.

[SUMMARY, ETC.:—(1) *Note at the time*: “The chief new result was the unacceptability of *Neptis swynnertoni*. The butterfly was to all appearance undamaged by its tasting and continued to move freely about the cage.”

(2) *Grades*:—

- (a) 1. Grasshopper, *P. cebrene*, and *P. natalensis* ☉ f.
- 2. *N. saclava*, *N. agatha*, *N. swynnertoni*, *P. lucretia*, *P. trimeni*, *P. lyceus*, *Ypthima*.
- (b) 1. *L. thalassina* ♂.
- 2. *N. saclava*.

The eating of *L. thalassina* failed to procure that of *P. trimeni*, and it is just possible therefrom that the *Pseudacraea* is not as high as *Leuceronia*; similarly, *M. agathina* pulled the roller up when she got “on the run” just afterwards, and *Mycalasis*, *Belenois*, &c., which failed to do so, were quite likely therefore less unpleasant than the *Mylothris*.]

Exp. 54.—June 28. To place *Pseudacraea*. Crushed and rejected with utter disgust the larva of *Acrea serena*, ate steadily after tasting it a ♂ *Phrissura isokani*, refused a ♂ *Mylothris agathina* (smelling strongly of sweet-brier) with shakes of the head, and tasted and at once threw away *Mylothris yulei*. A second *Phrissura isokani* was readily accepted, crushed, and swallowed.

I now offered a very large moth (*Nyctipao macrops*), with only two wings removed; the bird readily ate it, and then persistently refused to touch *Neptis saclava*. She accepted, however, crushed and tasted well, and swallowed *Neptis*

swynnertoni, again refused without tasting, most obstinately, *Neptis saclava*, tasted and crushed very thoroughly and swallowed *Papilio lyæus*, then refused but, on my continuing to hold it to her, tasted slightly and dropped *Pseudacræa trimeni*.

After a short interval she refused without tasting *Mylothris yulei* and *Mylothris agathina*, readily ate a *Charaxes brutus* with one wing, refused for a time quite decidedly *Neptis agatha* and *Neptis saclava*, but ate readily after thorough crushing *Pseudacræa lucretia*, *Ypthima*, and a second *Neptis agatha*, this one with all wings attached; then the *Neptis saclava*. "Appetite"—for butterflies of this category—"had evidently come in the eating" of the *Pseudacræa* (cf. yesterday's experiment).

She now ate a second but this time wingless *Charaxes brutus*, and tasted warily and emphatically threw away an *Ypthima*. I had only a dead and completely dried-up *Neptis* left (*Neptis saclava*), but, wishing to see whether it would be refused without tasting, offered it. The bird at once freely accepted it, thereby showing once more, I thought, that it preferred it to *Ypthima*, but, finding it doubtless to be dry and unattractive, pitched it right away.

[SUMMARY:—

- (a) 1. *C. brutus*, *P. isokani*, *N. macrops*, *N. swynnertoni*, and *P. lyæus*.
- 2. *M. yulei* and *M. agathina*, larva of *A. serena*.
- (b) 1. *N. swynnertoni*, *P. lyæus*, and *Ps. lucretia* apparently above
- 2. *N. saclava* (and *P. lucretia* above *N. agatha*).
- 3. (On manner) *Ypthima*.

As my object had been to compare *Pseudacræa trimeni* with *N. saclava* or *P. lucretia* (I had previously "placed" these two in the same grade) and I had none left, I discontinued. During the next two hours I was fortunate enough to secure both *N. saclava* and *P. lucretia*, and on my return, the *P. trimeni* being still alive, resumed the experiment.]

Exp. 55.—To place *Pseudacræa*. The roller had become fairly hungry in the interval, but tasted and rejected with the greatest promptness a larva of *Acraea serena* and refused *Mylothris yulei* without tasting. She now ate four small grasshoppers, and after them an *Ypthima*. She had evidently not quite reached the desired stage. A *Charaxes brutus* however carried her just too far, for she now obstinately refused without tasting a *Neptis saclava* and a second *Ypthima*. I therefore waited five minutes, when a *Henotesia perspicua* was also refused without tasting. Three minutes later the bird refused a *Neptis saclava* but tasted well and readily ate a *Eurytela dryope*.

Three minutes later again she crushed and as readily ate a *Neptis saclava*, refused an *Ypthima* most obstinately without trial, tasted and dropped a second *Neptis saclava*, evidently more ready to consider it, tasted very thoroughly and dropped both *Pseudacræa trimeni* and *Pseudacræa lucretia*, thus indicating that neither was more acceptable to her than the *Neptis*, tasted and at once rejected a *Byblia*, refusing to touch a second; refused but then, wavering, tasted and, evidently reassured, at once ate *Eurytela hiarbas* and after it, after thorough crushing, a *Papilio lyæus* ♀.

The bird had quite evidently just before arrived at the stage of wavering whether

to accept *Neptis saclava* and its like or to reject them, but the *Fapilio* had once more carried her on too far, for even ten minutes later she refused without tasting *Pseudacraea lucretia*; then barely tasted if at all *Pseudacraea trimeni* and refused to take it from the forceps, leant forward to take a *Neptis saclava* but thinking better of it at the last moment withdrew without having actually tasted it. The decisive moment was evidently however very near at hand, so giving the bird another two minutes—all I dared to risk—I offered the *Byblia*. She tasted it and then went on to crush it well and eat it, refused with a shake of the head, then, relenting, accepted, crushed very thoroughly and swallowed *Pseudacraea trimeni*, similarly refused *Pseudacraea lucretia*, but again relenting, tried it, crushed it thoroughly, and swallowed it. She next refused *Neptis saclava* too, but, changing her mind once more, tasted it very thoroughly indeed and finally flung it away; refused but, on tasting, ate without further hesitation a blackish skipper, after it tasting very thoroughly and eating with equal readiness a *Baoris*. She then tasted well and swallowed the *Neptis* which she had just rejected, and readily ate a *Gegenes*.

[SUMMARY, ETC.:—(1) *Note at the time*: “The difficulty of satisfactorily placing a butterfly of which one possesses only a single example is well illustrated by these experiments on *Pseudacraea trimeni*. It was not until late in the fifth experiment that I was at last successful, but the decisive and unequivocal nature of the result then obtained would have amply repaid a greater amount of trouble. I had before suspected, chiefly from the behaviour of the shrike, that *Pseudacraea trimeni* was decidedly pleasanter than *Pseudacraea lucretia*, but no doubt could possibly remain in the mind of anyone witnessing this concluding experiment that to the roller there is not a particle of difference between them in this respect, and that that between the *Pseudacraeas* and *Neptis saclava* is, if it exists at all, infinitesimal. I had the good fortune to bring the bird twice to the exact point at which she wavers over *Neptis* and other butterflies of the same calibre. On the first of these occasions she showed unmistakably that neither *Pseudacraea* is more acceptable than *Neptis saclava*, on the second that neither is less acceptable. The fact of having just eaten the two large *Pseudacraeas* would be sufficient to alter to a trifling extent the state of its appetite and to secure the rejection of the not more unpalatable *Neptis*, which was otherwise treated exactly similarly and in any case eaten [after stimulation] immediately afterwards.

The *Pseudacraea trimeni*, I may here mention, had been kept on fresh damp moss and remained alive up to the moment of its final disappearance down the throat of the roller.”

(2) *Grades*:—

- | | |
|--|--|
| | 1. <i>E. dryope</i> , <i>E. hiarbas</i> , blackish skipper. |
| <i>H. perspicua</i> (or, more likely, <i>M. campina</i> , with which <i>H. perspicua</i> seems to get confused). | 2. <i>N. saclava</i> , <i>P. trimeni</i> , <i>P. lucretia</i> , all about equal. |
| | 3. <i>Ypthima</i> . |
| | 4. Probably <i>M. yulei</i> and larva of <i>A. serena</i> ; for, though the first <i>Ypthima</i> may have been eaten under the stimulation of the grasshoppers, it is unlikely that any stimulation would at that stage have induced the roller to eat the <i>Mylothris</i> or larva.] |

Exp. 56.—June 29. Hungry; tasted and rejected *Acraea serena*, and after it with far more marked disgust its larva.

- [1. *A. serena*, imago.
- 2. Its larva.]

Exp. 57.—June 30. Refused to touch another grasshopper at the end of a large feed, by the forceps, of chiefly these insects, in spite of my best endeavours to tempt her. She now took but tossed carelessly away into the air a *Precis cebrene*, refused without tasting a *Precis archesia*, refused, then tasted and rejected a *Byblia*, but, attracted by the movements of a *Charaxes neanthes*, leant forward after for some time ignoring it and took, crushed, and swallowed it with evident approval. She now once more refused *Precis cebrene*, this time without tasting, was attracted by a fluttering *Gegenes* and tasted and rejected it; refused without tasting a *Hesperia*, tasted after first ignoring it a *Precis tugela* ♂ f., and, evidently liking it greatly, crushed and at once swallowed it, and readily accepted, crushed, and swallowed the *Precis archesia* and *P. cebrene* before refused. She then tasted and rejected, but on my again offering it crushed and tasted very thoroughly and finally swallowed the *Gegenes* reoffered, but looked quite doubtful about it, refused but then leaning forward tasted slightly and rejected a *Neptis saclava*, refused persistently without tasting an *Ypthima* and an *Acraea*-like *Baoris*, but after at first refusing it tasted, crushed, and readily swallowed a newly-emerged *Atella phalantha*. She now refused without tasting *Hamannuida daedalus*, *Pyrameis cardui*, and one of her favourite grasshoppers, but was tempted nevertheless by a *P. archesia* which she crushed and readily ate. After it, with equal readiness, she ate a *Precis natalensis* ♂ f.

After an interval I offered and the bird, noticeably hungrier, crushed and ate without hesitation *Papilio lyceus*, *Leuceronia thalassina* ♀, and the *Byblia* previously rejected, but she tasted and at once rejected *Neptis saclava*.

[SUMMARY, ETC.:—(1) *Note at the time*: “The bird was utterly replete, so much so that its acceptance under such circumstances of *Precis archesia*, *P. natalensis* ♂, *P. tugela*, *Atella phalantha*, and *Charaxes neanthes* would indicate that these five butterflies are exceedingly high-grade. The *Gegenes* was less liked.”

(2) *Grades*:—

- 1. *P. archesia* ♂ f.
- 2. *H. daedalus*, *P. cardui*, and a favourite grasshopper.

At first sight it would seem that many more preferences were shown, but I fear I cannot regard them as necessarily quite reliable. Thus *C. neanthes*, *P. tugela*, and *A. phalantha* were each eaten after initial refusal: might not the refusals of their respective predecessors have been turned into acceptances by just that extra amount of coaxing? And *P. archesia*, *P. cebrene*, and *P. natalensis* ♂ f. were each eaten after a possible whetting of the appetite. In the offerings after the interval the acceptances came first and the one refusal after them, so nothing can fairly be deduced.]

Exp. 58.—July 3. Tasted and at once rejected *Mylothris agathina* ♀, *Mylothris rueppelli*, and *Mylothris yulei*, but readily ate after crushing them *Phrissura*

isokani, an *Ypthima*, and two *Charaxes brutus*. She now tasted and rejected *Ypthima* and *Phrissura isokani*, and refused without tasting *Neptis agatha* and *Pinacopteryx pigea*, but then suddenly shaking out her feathers and rousing herself generally she not only crushed and ate the *Pinacopteryx* and the *Neptis agatha* but, only about three minutes later, a *Terias*.

I then gave several grasshoppers, after which she readily ate a *Neptis saclava*, several more grasshoppers, and after them yet another *Neptis saclava*. Then a few more grasshoppers, but they brought her to the point of repletion, for she now refused without tasting not only *Gegenes*, *Byblia*, and *N. saclava*, but a *Tagiades flesus* and a *Pyrameis*. She then crushed and swallowed *Hamanumida dædalus* after at first refusing it, crushed slightly and tossed carelessly away into the air a ♂ *Catopsilia florella* and a *Pyrameis cardui*, crushed and swallowed after at first refusing it a yellow ♀ *Catopsilia*, then refused without tasting *Salamis anacardii*, *Precis cebrene*, *Pyrameis cardui*, *Tagiades flesus*, *Hamanumida dædalus*, and ♂ *Leuceronia argia*.

[SUMMARY :—

1. *P. isokani*.

2. *M. agathina* ♀, *M. rueppelli*, *M. yulei*.

It would be unsafe to deduce anything further from an experiment showing such caprices of appetite.]

Exp. 59.—In the late afternoon, having kept the bird without food for some hours, I offered a *Terias*. She at first ignored it but finally just took it in the point of her bill and tossed it away, afterwards refusing with violent head-shakings, clapping of the bill, and other unmistakable signs of recognition and dislike, to touch a *Nychitona medusa*. A ♀ *Mylothris rueppelli* was, however, very thoroughly crushed and swallowed, though a ♀ *Mylothris agathina* and a ♀ *Mylothris yulei* were each at once rejected on being tasted. I now offered a ♂ *rueppelli*. This was accepted, very thoroughly crushed, and finally half-swallowed, but brought up again, again well crushed, and in the end dropped. On my twice reoffering it, it was the first time well crushed and dropped and on the second occasion just crushed slightly and rejected. *Mylothris agathina* and *Mylothris yulei* were reoffered, but the bird refused to have anything to do with them. There could be no doubt at all that the *M. rueppelli* was preferred to either (all were quite freshly caught) and that a very large *Terias* which I now offered was preferred to even *M. rueppelli*, for the bird just crushed it slightly and swallowed it. Evidently she had not quite "woken up" when I first offered it. Immediately afterwards she tasted and most emphatically rejected the *Nychitona* and an *Acraea serena*, shaking her head after each with marked disapproval. I then reoffered the *Mylothris rueppelli*, which was once more well crushed and rejected, the *Mylothris agathina*, which was recognized and refused with shakes of the head, and the *Mylothris yulei*, which was tasted and at once emphatically rejected. She now once more crushed and simply dropped the *M. rueppelli*, but ate with the greatest readiness a *Neptis saclava*. In order that the bird might the more readily differentiate them, I had offered throughout the *Mylothris*

rueppelli with a forewing attached, the *M. agathina* with a hindwing, and the *M. yulei* with both a fore- and a hindwing on the same side.

I now gave the bird four smallish grasshoppers, which were eagerly eaten—it was evident that she had been very fairly hungry. She then refused obstinately without tasting a small *Terias senegalensis*, refused only for a moment but then crushed and readily ate a *Neptis saclava*, again most obstinately refused the *Terias* without tasting, but readily ate after crushing them slightly a second *Neptis saclava* and an *Ypthima*.

She then, after eating a *Charaxes brutus* and a *Charaxes cithæron* (wingless), refused persistently without tasting a *Neptis saclava* and an *Ypthima*, but finally tasted the latter and emphatically flung it to the other side of the cage. She then tasted and rejected (but without emphasis) *Neptis saclava*.

I now gave her two wingless *Charaxes brutus* which were most readily eaten, and a *Papilio lyæus* with one wing which was crushed very thoroughly and eaten very waveringly.

Having eaten two more large *Charaxes (candiope)*, the bird obstinately refused a *Papilio lyæus*, refused but then tasted and rejected a *Leuceronia argia* ♂, and refused without tasting a ♂ *Catopsilia florella* but took a *C. cebrene*. But she was evidently replete, for after playing with and finally eating the *Precis cebrene* with undoubted disinclination, she simply crushed and dropped a *Pyrameis*. However, a *Charaxes neanthes* now attracted her curiosity by its violent movements and was crushed well and readily eaten, but the bird then merely took and tossed carelessly into the air in turn an *Atella phalantha*, a *Crenis boisduvali* or *natalensis*, a *Precis cebrene*, a *Pyrameis cardui*, and one of her favourite grasshoppers.

Five minutes later she crushed and readily enough ate a *Pyrameis*, refused positively without tasting the *Crenis* and a *Precis cebrene*, refused but at once changing her mind accepted, crushed well, and swallowed with evident appreciation a *Salamis anacardii*, and after it a large ♂ *Catopsilia*, refused obstinately without tasting a *Leuceronia argia* ♂, a *Pyrameis cardui*, a *Precis cebrene*, a *Melanitis leda*, and a second *Catopsilia florella*. I now reoffered the *Melanitis*, which was at first ignored but afterwards accepted, well crushed, and eaten. The bird then tasted and rejected *Leuceronia argia* ♀, but readily ate after crushing it a *Catopsilia florella*, then crushed and rejected a *Papilio lyæus* ♀.

Five minutes later she tasted and rejected *Leuceronia argia* ♂, but readily enough ate a *Pyrameis*, a *Precis cebrene*, the *Crenis*, a *Macroglossa trochilus*, and a *Pyrameis*, but was very evidently anything but hungry.

Five minutes later she tasted and rejected the *Leuceronia*, a *Eurytela hiarbas*, a light-coloured *Byblia*, readily enough ate a *Hamanumida dædalus*, and a *Rhopalocampta libeon* without smell, refused obstinately without tasting a dark *Byblia*, but readily ate a *Tagiades flesus* and a *Rhopalocampta pisistratus* without trace of smell.

Five minutes later she refused without tasting the *Leuceronia*, *Hamanumida dædalus*, *Precis cebrene*, and *Pyrameis cardui*, being evidently satisfied. Finally, much bored by my attempts at persuasion, she retired to the furthest perch and turned her back to me.

An hour later, by lantern-light, I offered an *Ypthima* and a *Neptis saclava*, each

of which was tasted and promptly rejected. The *Leuceronia argia* ♂ was, however, eaten after very thorough crushing; *Eurytela hiarbas* with two wings was crushed and rejected, and *Papilio lyæus* ♀ was very thoroughly crushed and swallowed. The bird then tasted and rejected *Eurytela hiarbas* with only a hindwing, tasted and at once readily swallowed a *Precis cebrene*, crushed well and rejected the *Eurytela*, this time without wings, and tasted and very emphatically rejected the dark *Byblia*.

The bird certainly gave everything a much fairer tasting than usual in this last experiment, being probably unable to distinguish the colours well by lantern-light.

[SUMMARY, ETC. :—(1) *Note at the time* : “The object of the whole experiment had been to place *Crenis*, and to obtain a further opinion from the roller on the relative unpalatability of *Catopsilia florella*, *Leuceronia argia*, *Papilio lyæus*, and *Eurytela hiarbas*. In this I partly failed, but the bird was throughout in excellent form and the results, so far as they went, appeared to me to be particularly trustworthy. *Atella* was unluckily lost, so could not be reoffered.”

(2) *Grades* :—

1. *S. anacardii* and perhaps *C. neanthes*.
2. *P. cebrene*,
3. *C. florella*, } *P. cardui*, *H. dædalus*, and *T. flesus*.
4. *L. argia* ♂ and *P. lyæus* ♀.
5. *E. hiarbas*.
6. *N. saclava* and *Byblia*.
7. *Ypthima* and *Terias senegalensis*.
8. *M. rueppelli* ♂ and ♀.
9. *M. agathina* ♀ and *M. yulei* ♀.
10. *N. medusa* and *A. serena*.

One link in the above was weak, and to mend it I had to use my knowledge (from other experiments) that *Byblia* and *N. saclava* are approximately equal in the roller's estimation.

Actually *Ypthima* was eaten in apparent preference to *Terias senegalensis*, and were it not for the possibility of special stimulation would constitute an additional grade between *Neptis* (definitely preferred to *Terias*) and *Terias*. Were it not for the same complication *R. libeon* and *R. pisistratus*, the *Crenis*, and *Macroglossa trochilus* might be inserted on a level with at any rate *Pyrameis*.

But even without all this the results are very full, and I have not hesitated to deduce from differences in manner which were particularly good in this experiment.]

Exp. 60.—*July 4.* Crushed and rejected *Mylothris yulei*, but readily ate *Neptis saclava*, and after it a few small grasshoppers and another *Neptis saclava*.

I now offered two large grasshoppers which were readily eaten, the bird then tasting and rejecting a *Byblia* but crushing and readily eating a *Neptis agatha*. She next refused for some time but finally crushed well and swallowed a *Neptis*

saclava, tasted and rejected *Phrissura isokani*, refused an *Ypthima* and the *Byblia* persistently without tasting, then tasted the *Ypthima* reoffered, and rejected it, refused for a second or two only (thinking of *saclava* ?) but changing her mind accepted and ate *Neptis agatha*, then tasted and rejected the *Byblia* (a dark individual) and a *Phrissura isokani*, and refused obstinately to touch an *Ypthima*. I now offered a large brightly-coloured strongly-smelling locust, *Phymateus viridipes*. The bird at once seized on it, but after running it through her bill and tasting it well all over without however actually crushing it, dropped it, but without special sign of dislike. She refused it without tasting on its being reoffered.

Exp. 61.—In the late afternoon I offered the bird *Mylothris rueppelli* ♂. This, after at first refusing, she tasted and at once rejected, then refused for some time but finally accepted, crushed, and swallowed without further hesitation a *Terias brigitta*, after this once more tasting slightly and rejecting the *Mylothris rueppelli*.

I now gave her the *Phymateus viridipes*, which she accepted, crushed and battered very thoroughly indeed against the perch, taking some time over it, so that her mouth must have been full of its taste, and finally ate it without hesitation or any sign of dislike. She then obstinately refused to touch *Terias brigitta* or a *Phrissura isokani*, crushed thoroughly and threw away an *Ypthima*, refused without tasting a *Byblia*, readily accepted a *Neptis saclava*, crushed and swallowed it, and after it an *Ypthima*, once more refusing to have anything to do with the *Terias* or with *Phrissura isokani* ♂ or ♀.

I now gave her a large grasshopper and a small one. She then crushed and dropped but on my reoffering each crushed once more well and swallowed a *Papilio lyceus* and a *Leuceronia thalassina*. I could see no difference in her treatment of the two species.

She then readily ate a *Charaxes brutus*, afterwards crushing and rejecting a *Papilio lyceus*, and refusing for some time but in the end, on my removing the wing, similarly crushing and rejecting *Leuceronia argia* ♀.

[SUMMARY, ETC.:—(1) *Note at the time*: "There seemed to be nothing much to choose in point of acceptability between *Papilio lyceus* and the *L. thalassina*. The roller yesterday showed rather more suspicion of *Leuceronia argia* until I removed the wing. Perhaps the latter reminded it too much of that of *Mylothris agathina*.

Phymateus viridipes, on the strength of having found which genus in their stomachs both Marshall and I based an idea of the indiscriminate tastes of rollers in general, is here shown to be lower, probably, than *Neptis saclava* and *agatha*, but probably rather higher than *Terias brigitta*—though its more deliberate crushing may have been merely because less well known of late than the *Terias*."

(2) *Grades*:—

- | | | |
|-------------------|---|--|
| | 1. <i>Charaxes brutus</i> , on manner above | |
| | 2. <i>L. thalassina</i> and <i>P. lyceus</i> , <i>N. agatha</i> and <i>N. saclava</i> . | |
| | 3. <i>Ypthima</i> . | |
| <i>M. yulei</i> . | 4. <i>Terias brigitta</i> . | } <i>Phymateus viridipes</i> , <i>Byblia</i> , and <i>P. isokani</i> . |
| | 5. <i>Mylothris rueppelli</i> .] | |

Exp. 62.—*July 5.* Tasted and at once rejected *Acraea caldarena* and refused without tasting *Acraea acara* and *Amauris lobengula*. She then ate several grasshoppers, crushed and rejected *Mylothris rueppelli*, and obstinately refused without tasting a *Terias*, but readily ate a *Neptis saclava* and an *Ypthima*, rejected after tasting it a *Phrissura isokani*, crushed and dropped but on my reoffering it ate readily a *Rhopalocampta forestan* with a very strong *Amauris*-smell, which was presumably what obtained its rejection when first tasted.

Fifteen minutes later, after an interruption, she refused without tasting a *Terias*, refused, then tasted and rejected a *Phrissura isokani*, and ate with the greatest readiness and no sign of dislike seven *Neptis saclava*, one *Ypthima*, and one *Neptis goochi* in rapid succession, first slightly crushing each.

She now ate five small grasshoppers, refused without tasting a *Neptis saclava* and an *Ypthima*, refused, then tasted *Neptis goochi*, but at once emphatically rejected it and proceeded to wipe her bill vigorously on the perch, refusing then without tasting a *Neptis agatha*.

After three more small grasshoppers she tasted and rejected a *Papilio lyceus* ♀, persistently without tasting refused a *Leuceronia argia* ♂ (as always, with one hindwing), but recognized and at once crushed and readily ate a *Catopsilia florella*, differing hardly at all in general appearance from the *Leuceronia* except in the latter's greener and more conspicuous eyes. She then once more refused without tasting the *Leuceronia argia*, also a *Eurytela dryope*, then leaned forward, barely tasted the *argia*, and withdrew, leaving it in the forceps. However, she was evidently replete in any case, for she now just crushed and dropped or refused without tasting several edible grasshoppers and refused again without tasting *Precis cebrene*, *Pyrameis cardui*, and *Precis archesia*.

Ten minutes later she tasted warily and rejected *Leuceronia argia* ♂ and *Eurytela dryope*, but crushed and ate with apparent relish a large green Pentatomid bug, *Encosternum delegorguei*.

I continued the experiment—one object of which was to obtain an opinion from the bird on the relative merits of *Leuceronia* and *Papilio lyceus*—an hour later, by lamplight. She commenced by tasting and rejecting *Eurytela hiarbas*, then crushed and readily ate *Papilio lyceus*, *Leuceronia argia* ♂, and a *Charaxes brutus*, crushed and dropped but on my reoffering it crushed very thoroughly and ate *Papilio lyceus*, tasted suspiciously or with disinclination and rejected two ♀ *Leuceronia argia* in succession, accepted readily but after crushing it well with a doubtful look threw away *Papilio dardanus* ♂, and once more tasted and rejected *Eurytela dryope* and the two *Leuceronia argia* ♀s. She now for some time refused to touch *Papilio dardanus* ♂, then crushed and rejected it, but on my reoffering and continuing to hold it to her, crushed it well and swallowed it with evident suspicion or disinclination.

She next refused persistently without tasting but in the end tasted and once more rejected both the *Leuceronia argia* ♀s, tasted slightly (after at first refusing) and rejected *Eurytela dryope*, but crushed and readily ate a "swift" moth with very slight tomato-smell, ten minutes later again tasting and rejecting *Leuceronia argia* ♀ and *Eurytela dryope*.

I now gave her a few grasshoppers, and on her refusing absolutely to touch another offered her a *Pyrameis cardui*, a *Precis archesia*, a *Catopsilia florella*, and a *Precis cebrene*, all of which were persistently refused without tasting.

Ten minutes later the bird tasted and rejected *Leuceronia argia* ♀ and *Eurytela dryope*, ate readily after slightly crushing each two *Precis archesia* and a *Precis elgiva*, but was evidently nearly replete, for she now just crushed slightly and threw aside a second *Precis elgiva* and a *Pyrameis cardui* and refused without tasting a *Precis cebrene* and a *Precis natalensis* ♂ f.

Five minutes later she refused without tasting *Precis elgiva*, *Pyrameis cardui*, *Precis cebrene*, *Precis antilope*, and *Cyrestis camillus*, crushed slightly and dropped *Precis natalensis* ♂ f., crushed and ate a yellow *Catopsilia*, and then crushed and readily ate the ♂ *Precis natalensis* on my reoffering it. She then crushed and tossed aside a *Pyrameis*, refused without tasting a *Precis cebrene*, crushed and swallowed a *Hamanumida dædalus*, again refused without tasting a *P. cebrene*, but crushed and swallowed a second *H. dædalus*, refused without tasting a *Precis antilope*, and crushed and readily ate an *Atella phalantha*.

Only three minutes later she readily ate, after slightly crushing each, the *Precis antilope*, a common cockroach, a *Precis cebrene*, a *Pyrameis cardui*, and a *Precis clelia*, refused obstinately without tasting a *Cyrestis camillus* and a *Teracolus* (?) (mimic of *Leptosia*), refused, then crushed and swallowed a *Hesperia* without smell, and refused, then tasted very slightly and dropped a dark skipper, afterwards refusing it persistently without tasting.

[SUMMARY :—(1) *Grades* :—

(a)

- | | | |
|---|---|---|
| 1. Swift-moth and
<i>Encosternum</i>
<i>delegorguei</i> . | { | 1. Grasshoppers, <i>C. florella</i> , <i>H. dædalus</i> , <i>A. phalantha</i> . |
| 2. <i>P. lyæus</i> . | | 2. <i>P. elgiva</i> , <i>P. cebrene</i> , <i>P. antilope</i> , and <i>P. natalensis</i> ♂ f.,
<i>P. dardanus</i> perhaps slightly above <i>L. argia</i> on manner. |
| 3. <i>E. hiarbas</i> . | { | 3. Probably (for they were below <i>P. archesia</i>) <i>L. argia</i> ♀ and
<i>E. dryope</i> . |

With 2 and 3 may also be bracketed *P. cardui*, *N. saclava*, *N. agatha*, *N. goochi*, and *Ypthima*. Also whatever the *Cyrestis* (not tasted) and *Teracolus* were taken for.

(b) 1. *C. florella*. } *R. forestan*.

2. *N. saclava*. }

3. *Terias*, *P. isokani*, *M. rueppelli*, *A. caldarena*, *A. acræa*,
A. lobengula.

The hasty dropping of the *R. forestan*, probably on account of its *Amauris*-like smell, reminds one of the bird's dropping of the Cetoniid, *Neptunides polychrous*, on its commencing to buzz.

(2) A note states the following order, based presumably mainly on manner :—

- | | | |
|-------------------------|---|--------------------|
| 1. <i>P. lyæus</i> . | { | <i>E. dryope</i> . |
| 2. <i>P. dardanus</i> . | | |
| 3. <i>L. argia</i> ♀. | | |
| 4. <i>E. hiarbas</i> . | | |

As it was made with the experiment fresh in my mind it deserves consideration, but I should not deduce quite so much from the experiment as it stands recorded.

(3) *P. antilope*, *P. cebrene*, *P. clelia*, *P. cardui*, a *Hesperia*, and a common cockroach were all, even allowing for special stimulation, eaten fairly near repletion-point.

(4) The recognition and ready acceptance of *Catopsilia* after an obstinate refusal of *Leuceronia argia* ♂, differing from it in appearance chiefly (to speak roughly) in the colour and greater prominence of the eyes, suggests perhaps how such fine points in mimicry as the fulvous palpi of *Pseudacraea trimeni* may have been brought about. It must be remembered that the capture of an insect is not equivalent to its death, which would usually only take place as the result of the subsequent crushing process. Small resemblances which can only be detected at the closest quarters, as when the insect is already in the bill, will therefore have a chance of counting.]

Exp. 63.—*July 6.* I had put in a handful of grasshoppers and other Orthoptera, nearly all of which probably belonged to high-grade species. The bird merely leant over and scanned them from her perch at the top of the cage, then resumed her usual position of repose with a shake of the head that seemed to indicate "No, I can't be bothered to go down."

Half an hour later, as the grasshoppers still remained untouched, I offered the smaller ones one by one in the forceps. The bird readily ate eight, then refused persistently without tasting an *Ypthima*, a *Pseudacraea lucretia*, and a *Teracolus*, ate another grasshopper, but merely crushed and threw away a second and refused without tasting all of many others that I now offered her. She also refused without tasting a *Cyrestis camillus*, a *Leuceronia argia* ♀ (without wings) and a *Eurytela dryope*, but quite readily accepted and ate a *Precis cebrene*.

Later, by lamplight, she crushed and readily swallowed *Leuceronia argia* ♀, tasted and rejected *Eurytela dryope*, *Cyrestis camillus*, an *Ypthima*, a *Teracolus* (?), and, after thorough crushing, *Pseudacraea lucretia* and again the *Cyrestis*. She then ate with relish *Pyrameis cardui* and *Precis cebrene*, and after them the *Eurytela dryope* and the *Pseudacraea* (with all wings) after prolonged crushing, tasted and rejected once more the *Cyrestis*, refused, then changing her mind crushed and swallowed the *Teracolus*, rejected a dead but supple *Neptis goochi*, but on its being reoffered ate not only it but a second, and refused a *Terias brigitta* (?). She finally, however, tasted and rejected it.

[SUMMARY:—

- (a) 1. *P. cebrene*.
- 2. Grasshoppers.
- 3. *C. camillus*, *E. dryope*, *L. argia* ♀.
- (b) 1. *Pyrameis cardui*.
- 2. *C. camillus*, *E. dryope*, *Ypthima*.

It is probable that *E. dryope*, *C. camillus*, *Ypthima* and the *Teracolus* were

at any rate not liked better than *L. argia* ♀, *Cyrestis camillus* than *Ps. lucretia*, or *T. brigitta* than *N. goochi* and the *Teracolus*.]

Exp. 64.—*July 7.* I fed the roller by hand on grasshoppers &c. until she would eat no more. She then crushed and tossed carelessly aside a *Precis cebrene*, examined critically and shook her head at a large wasp, *Belonogaster dubius* (which I killed immediately before offering it), but changing her mind tasted it slightly and dropped it. On my reoffering it, she ran it through her bill from side to side, tasting it well, and dropped it. I reoffered it once more, when it was merely tasted slightly and dropped.

Ten minutes later, evidently still replete, she at first ignored, but then took, crushed and swallowed *Precis cebrene*, and crushed slightly and tossed aside the hornet.

Ten minutes later she refused, then tasted slightly and dropped the hornet, but readily ate a *Precis cebrene*.

Twenty minutes later she refused persistently without tasting an *Ypthima*, an Acræoid skipper (*Baoris nyassæ*), and a Lycoid moth, but ate readily *Precis cebrene*, and after at first dropping it crushed very thoroughly and swallowed the hornet—without sign of dislike. She then crushed slightly and swallowed a *Precis clelia*, again refused the skipper and the Lycoid moth, then tasting the latter slightly (it had no smell that I could detect) rejected it, ate readily a *Pyrameis*, but tasted and at once rejected a *Neptis saclava*, readily accepted and ate a *Precis cebrene*, but tasted slightly and rejected the Lycoid moth, crushed and dropped, probably accidentally, a *Papilio lyæus* and on my reoffering it crushed it well and swallowed it without apparent dislike, refused without tasting the Lycoid moth, tasted and promptly rejected *Neptis agatha*, and crushed and at once swallowed a *Hesperia* (of usual species) with slight bug-smell.

[SUMMARY:—

- | | | |
|-----|--|---|
| (a) | 1. <i>P. cebrene</i> . | } <i>P. cardui</i> , <i>P. lyæus</i> ,
<i>Hesperia</i> . |
| | 2. <i>Bel. dubius</i> , probably but not certainly
above "3." | |
| | 3. <i>Ypthima</i> and the Lycoid moth. | |
| (b) | 1. <i>P. cebrene</i> and probably <i>P. lyæus</i> . | |
| | 2. <i>N. saclava</i> . | |
| (c) | 1. <i>Hesperia</i> sp. (bug-like smell). | |
| | 2. <i>N. agatha</i> , which probably not above <i>P. lyæus</i> . | |

The roller's treatment of the *Belonogaster* precluded the idea that the sting may have had anything to do with its placing.

The Acræoid skipper was probably refused through its likeness to an *Acræa*. Similarly, it is quite probable that the first refusal of the Lycoid moth was not on its own known merits.]

Exp. 65.—*July 9.* Rejected with the greatest emphasis a larva of *Acræa serena*
[State of hunger unfortunately not indicated.]

Exp. 66.—*July 11.* Hungry, ate two small pieces of meat, crushed and tasted well and swallowed without any hesitation a pupa of *Acræa serena*, then recognized and refused its larva without tasting and with violent shakes of the head. She then crushed and readily ate a *Terias* and *Belenois severina*, but tasted and threw right away a ♂ *Mylothris agathina*.

[At the time I was convinced that the *serena* pupa was far better liked than the larva, even perhaps than *M. agathina* ♂, and commented—"The roller's behaviour on being shown the larva to-day was indicative of nothing less than horror." Reading the experiment now, and contrasting the great difference in manner, I still think that I may have been right, but it does not necessarily follow from the experiment. The possibility of special stimulation by the meat and inhibition by the pupa, and the fact that the acceptance and refusals came in the wrong order, necessitates caution. *Terias* was preferred to the *serena* larva, and probably ♂ *M. agathina* was liked at any rate not better than *B. severina*.]

Exp. 67.—*August 1.* Hungry; tasted and at once rejected *Mylothris agathina*, readily accepted, crushed, and ate two *Terias senegalensis*, accepted, crushed and battered very thoroughly, and finally swallowed a large dark green *Phymateus* with a strong unpleasant smell reminding one of *Cascara sagrada* and the leaves of *Datura Stramonium*. She now refused without tasting *Terias senegalensis*, tasted slightly and rejected the common Coccinellid, *Epilachna hirta* (exuding a yellow juice), refused persistently without tasting and with violent and continued shakes of the head a large, brilliant-metallic, black-spotted bug, *Cryptacrus comes*, common on *Croton sylvaticum*, readily accepted, crushed, and ate *Neptis saclava*, and refused obstinately without tasting it a second dark green *Phymateus*.

The refusal of the second *Terias* was evidently simply due to the *Phymateus* having filled the roller's stomach to a point in advance of the *Terias*-eating stage. All that can be deduced with regard to the *Phymateus* (which was exuding bubbles from behind its posterior pair of legs) is that it is likely to be unpleasanter than *Neptis saclava* and less so than *Mylothris agathina*. It is probably on a level with *Terias*. The refusal of the *Cryptacrus comes* (which I have found in the stomach of a wild bulbul, *Pycnonotus layardi*, v. 'Ibis,' 1908, p. 66) may have been due (1) to a previous knowledge of it or (2) to a mere distrust of its gaudy coloration.

I now proceeded to feed the bird up on grasshoppers, etc., until she absolutely refused to touch another. She then tasted and rejected *Eurytela dryope*, leaned forward evidently much tempted by a huge green Pentatomid bug, *Encosternum delegorguei*, which I now passed through the bars, but withdrew with a shake of the head without having tasted it, and refused without tasting *Antanartia scheneia* and *Precis cebrene*.

Ten minutes later she refused without tasting *Eurytela dryope*, *Antanartia scheneia*, and *Precis cebrene*, but accepted, crushed very thoroughly, and swallowed head first the big green *Encosternum* (it smelt very strongly on being crushed, not much before), and once more refused *Precis cebrene* and a common small grey Pentatomid bug. She kept on opening her mouth, doubtless in connection with what she had just swallowed, but whether this was to be interpreted as a sign of pleasure or the reverse I could not say.

Fifteen minutes later she tasted and rejected *Eurytela dryope*, but crushed and readily ate *Papilio lyæus* and *Papilio demodocus*, then obstinately refused *Eurytela dryope* without tasting, then ate four smallish grasshoppers and refused the next, also refusing *Papilio lyæus*, then three more grasshoppers and refused the next, also *Antanartia schœneia*. After a short interval *A. schœneia* and *P. cebrene* were once more offered, as well as a number of grasshoppers, but all were refused without tasting.

[SUMMARY:—(1) "There could be no doubt of the roller's enjoyment of the *Encosternum*, which was eaten in preference to the usually highly-placed *Precis cebrene*."

(2) *Grades*:—

- (a) 1. *N. saclava*.
Cryptacrus { 2. *Terias senegalensis* and *Phymateus* (latter if not result of
comes. { stimulation).
E. hirta. { 3. *M. agathina*.
(b) 1. *Encosternum delegorguei* (small grey sp., at any rate, not
liked better).
A. schœneia. { 2. Grasshoppers.
P. cebrene. { 3. *P. lyæus* (and *P. demodocus* ??).
{ 4. *E. dryope*.]

Exp. 68.—August 6. Tasted and rejected *Mylothris agathina* ♀ and *Terias brigitta*, afterwards refusing to touch the latter most obstinately. I then offered it a dull green *Phymateus* (a large specimen). The bird, though hungry, refused to have anything to do with it, retreating away along the perch whenever I brought it near. I then substituted for it *Phymateus viridipes*. The roller, which had retired to an inaccessible corner, at once on seeing it flew up, seized it, and after crushing it well, swallowed it with no indication of dislike. She then tasted and rejected once more the *Terias*, but crushed and very readily ate an *Ypthima*, of which there are still a good many about.

[SUMMARY:—(1) *Note*: "The dark green *Phymateus* was remembered with such evident dislike that though there was still nothing to indicate that it should be placed below *Terias* it would, I believe, have been placed well below it had the bird been hungry enough to eat that butterfly. The red-winged *Phymateus viridipes* was liked very much better, though not necessarily more than *Ypthima*."

(2) *Grades*:—

1. Red-winged *Phymateus* and *Ypthima*.
2. Dark green *Phymateus*, *T. brigitta*, and *M. agathina* ♀.]

Exp. 69.—August 7. Refused without tasting, then simply took from the forceps and threw away *Mylothris agathina*, refused also but then tasted slightly and threw away a *Terias*, but crushed and readily ate a *Mycalesis campina*, tried to crush but finally rejected in annoyance or despair a very hard *Acridium lineatum*, ate three smallish grasshoppers, refused persistently without tasting *Neptis saclava*, crushed and at once rejected *Eurytela dryope*, crushed well and rejected, though less promptly than the *Eurytela*, a *Leuceronia argia* ♀, and crushed and ate (it

took it some time to get it into good head-first position, with the result that it must have tasted it very thoroughly) a *Papilio lyæus* ♀. All these tastings were thorough and satisfactory.

Five minutes later she crushed well and ate *Leuceronia argia* ♀, refused without tasting, then tasted slightly and rejected *Eurytela dryope*, but crushed and readily ate a *Henotesia perspicua*. She then once more refused but ended by slightly tasting and rejecting *Eurytela dryope*, but on my reoffering it ate not only it but *Neptis agatha*. It then refused for a time an *Ypthima*, but on my continuing to hold it to her crushed and swallowed it.

[SUMMARY :—

- (a) 1. *M. campina*, small grasshoppers.
- 2. *M. agathina* and *Terias* (and small grasshoppers above *Acridium lineatum*).
- (b) 1. *P. lyæus* ♀. } *H. perspicua*.
- 2. *L. argia* ♀ }
- 3. *E. dryope*, *N. saclava*, *Acridium lineatum*, and *Terias*.]

Exp. 70.—August 8. Refused persistently without tasting *Mylothris agathina* ♀ and a *Terias*. She then ate several grasshoppers of various species, but finally, through sheer repletion apparently, refused to touch any more. She now refused and then carelessly crushed and tossed aside a *Precis cebrene* and an *Antanartia schœneia*.

Four minutes later she once more took *Precis cebrene* in the tip of her bill after at first refusing it and tossed it away.

Fifteen minutes later she readily ate a *Precis cebrene*, a *Papilio lyæus*, and a medium-sized grasshopper, but refused without tasting the next grasshopper (usually a favourite), also *Charaxes brutus*, and refused, then crushed and tossed aside, but on my offering for the third time once more crushed and this time swallowed a ♀ *Papilio lyæus*. I now offered her several species of grasshoppers, including most of her favourites, and she refused to touch any of them, then simply played with *Charaxes brutus* and *Precis cebrene*, tossing them into the air and catching them, and finally allowing each to fall. *Papilio lyæus* was tasted and rejected, and an *Antanartia* was taken, crushed slightly, and listlessly tossed away into the air. She then took a *Euralia mima* and was crushing it in the same careless fashion when, evidently specially attracted by it, she suddenly set to work more energetically, worked it round into a good head-first position, crushing it well the while, and swallowing it hindwing and all, though the latter was a distinct hindrance to the butterfly's passage. (N.B. The *Charaxes brutus* had been wingless.) She now obstinately refused to touch *Papilio lyæus*, *Precis cebrene*, *Charaxes brutus*, *Pyrameis cardui*, *Antanartia schœneia*, or any of the series of grasshoppers which I had offered previously.

Ten minutes later, still evidently feeling replete, she refused, then just took and tossed away, an *Antanartia schœneia* and a *Precis cebrene*, and refused without tasting *Charaxes brutus* and the grasshoppers.

[SUMMARY :—(1) Note at the time : "In view of her inability (through repletion) to eat either the *Charaxes*, the *Junonia*, or her favourite grasshoppers, it came as

a surprise to me that she was so immensely attracted by the *Euralia*, which she ate with unmistakable relish. Evidently to her it was very acceptable indeed."

(2) *Grades*:—

1. *Euralia mima*.
2. *P. cebrene*, *C. brutus*, *A. schæneia*, *P. lyæus*.

The previous *P. lyæus* was accepted only near repletion-point, but in view of its refusal and rejection just before, and the obvious growth of appetite required to get it accepted, it cannot be placed necessarily above *C. brutus*.]

Exp. 71.—August 11. Very hungry; readily accepted and ate *Terias brigitta*, then, very hesitatingly, a *Mylothris agathina* ♀ with very little smell, crushed and rejected a *Mylothris rueppelli*, crushed it very thoroughly indeed and finally rejected it on its being reoffered, then refused and, on my persisting, tasted and at once rejected a *Mylothris agathina* ♂ with the usual sweet-brier scent, but readily accepted and ate a *Terias senegalensis*. I then offered her the dull green and blue *Phymateus*. It was accepted, crushed very thoroughly, and at last swallowed. The bird then refused but, on my continuing to offer it, tasted and rejected *Terias brigitta*, but crushed and very readily ate *Belenois severina*, once more refusing the *Terias* without tasting. She then eagerly ate several grasshoppers, readily ate *Neptis agatha*, refused obstinately to touch *Belenois severina*, but once more readily accepted and ate *Neptis agatha*.

I then gave her six small grasshoppers, after which she crushed and ate *Eurytela dryope*, refused without tasting *Neptis agatha*, and tasted very slightly and threw aside a second *Eurytela dryope*, readily eating, however, a *Papilio lyæus*. She next refused, then tasted and rejected *Leuceronia thalassina* ♂, refused, then tasted, crushed and ate *Papilio demodocus*, tasted and rejected *Papilio angolanus*, then refused persistently without tasting *Papilio demodocus* and *Papilio lyæus*, also the red-winged *Phymateus viridipes*, which was offered with its wings spread and ignored. I then closed its wings and reoffered it in that position. The bird, which was at the further end of a perch, at once sidled up, looked at it closely, and then at once sidled back again without touching it.

Ten minutes later she readily ate *Papilio lyæus*, but crushed and rejected *Leuceronia thalassina* ♂ and *Papilio angolanus*, refused momentarily, then accepted, crushed well, and ate *Papilio demodocus* and, evidently just too replete for it, persistently refused *Papilio lyæus* without tasting.

After an interval she crushed well and very nearly ate *Leuceronia thalassina* ♂, but at the last moment rejected it, then refused without tasting *Eurytela dryope*, tasted and rejected the *Phymateus viridipes*, and refused without tasting *Papilio lyæus*.

An hour later she tasted and rejected *Neptis agatha* and *Eurytela dryope*, but ate readily *Leuceronia argia* ♀, crushed thoroughly for a long time and rejected the *Phymateus viridipes*, then, suddenly waking up, readily ate *Eurytela dryope* and *Neptis agatha*, tasted and rejected the *Phymateus*, ate readily a *Papilio lyæus* and a *Neptis agatha*, but tasted and rejected a *Terias brigitta*, as also once more the *Phymateus viridipes*.

[SUMMARY :—

- (a) 1. *N. agatha*.
 2. *B. severina*.
 3. *T. senegalensis*.
 4. *M. rueppelli* and *M. agathina*.
- (b) 1. *P. lyceus*, *P. demodocus*, and *L. argia*.
L. thalassina ♂ . } 2. *E. dryope*.
N. agatha. }
P. angolanus. } 3. Red *Phymateus*.

In arranging (b) I am assuming to be correct the indication that *P. lyceus* was not appreciably better liked than *P. demodocus*. *L. argia* having been placed above *E. dryope* and *L. thalassina* below *P. demodocus*, it is possible that the two Leuceronias should together form a grade intermediate between 1 and 2.]

Exp. 72.—August 21. Crushed and at once rejected *Mylothris agathina* ♂, readily ate *Neptis agatha*, eight small grasshoppers and a second *Neptis agatha*, tasted and rejected a *Mycalesis campina*, tasted and rejected a Syntomid moth (*Syntomis cerbera*) offered without wings, readily ate a large Coreid bug with strong smell (*Petascelis remipes*) after crushing it well, also a third *Neptis agatha*. She then tasted well and rejected an Ichneumon, *Osprynchotus flavipes*, also a second *Syntomis cerbera* (with wings), then crushed well and readily ate a second large Coreid bug of the same species, tasted very slightly, suspicious perhaps of the colour, and rejected and afterwards refused without tasting a small bright red beetle, crushed very well and rejected doubtfully the pupa of *Acrea serena*, refused, then barely tasted if at all a *Teracolus* with one forewing attached and dropped it.

A large baboon was at this moment detected watching us intently from an eminence close by, doubtless awaiting an opportunity of slipping in amongst the ripening coffee. I could not resist the temptation of a shot. On my return not many minutes later I gave the bird six very small grasshoppers to balance any alteration of appetite that the delay might have occasioned. She evidently, however, still remained somewhat hungrier than before (or was whetted by the grasshoppers), for she now ate not only a *Neptis agatha* and the *Teracolus* (after at first refusing the latter without tasting), but also a *Mycalesis campina*. I had no *Belenois* or *Terias* at the moment to offer, but the bird tasted and once more rejected *Mylothris agathina* with marked disgust.

A second interruption, longer than the first, now occurred. After it the bird played for a few seconds with *Mylothris agathina* ♂, repeatedly tossing it into the air and catching it. The last time she did not trouble to take it as it descended, and on my reoffering it refused it without tasting. She next tasted and at once rejected the first *Syntomis cerbera*, crushed and tasted very thoroughly indeed, running it time after time through her bill and evidently doubtful whether to swallow it, the pupa of *Acrea serena*, from which the juices were already exuding as the result of the first tasting. She at last swallowed it, but had barely done so when she at once brought it up again and rejected it, afterwards refusing it without tasting. She then refused without tasting, but on my continuing to offer it, crushed and at once rejected the large common orange and black Ichneumon, *Osprynchotus flavipes*,

as also a smaller one, probably the ♂, this time without wings, tasted and rejected and then refused persistently to taste again a "red-cross" *Lygæus* bug, without the usual bug smell but with a *very* faint smell of its own. I was a little doubtful of the value of the tasting, so I brought the usual grasshopper tin into view of the cage, having previously inserted the bug into it. The bird, as I knew it would, recognized the tin, at once came forward eagerly and ate readily and apparently almost without tasting the first five very small grasshoppers that I offered. I now quickly offered the bug. The bird accepted it in all confidence and without troubling to first glance at it, but at once, in the very act of throwing up her head to jerk it into the back of her throat, recognized it as unpleasant, and at once checking herself flung it to the other side of the cage. I twice again played the same trick, offering first a very small grasshopper which was eagerly eaten, and then the bug, which was each time taken as thoughtlessly as at first, but at once recognized by taste and flung away with unmistakable signs of dislike.

I then gave ten more very small grasshoppers, after which *Papilio lyæus*, *Papilio dardanus* ♂, and *Eurytela dryope* were readily accepted and eaten. Not replete enough for my purpose.

After seven more the bird rejected *Eurytela dryope* (it had, however, owing to its fluttering, for I had not removed the wings, considerable difficulty in getting it into good position for swallowing—hence probably the rejection), but ate *Neptis agatha*, and after it, readily enough, *Eurytela dryope*, first, as usual, crushing each.

After the next seven small grasshoppers a *Papilio lyæus* was crushed a good deal and eaten with considerable deliberation. A *Papilio dardanus* was crushed and fairly readily swallowed (slightly more readily to all appearance than the *Papilio lyæus*), and a *Eurytela dryope* was persistently refused without tasting. The bird then accepted and crushed a *Leuceronia thalassina* ♂, but made no attempt to swallow it, her attention being diverted by a shrike (*Dryoscopus cubla*), which at that moment had struck up its loud "Trek-whi-wheoo" notes in a tree close by, and was being answered by the captive bulbuls. This went on for three or four minutes, the roller all the time craning forward and listening intently, with her head on one side and the uneaten *Leuceronia* in the point of her bill. The shrike now suddenly stopped its song and the roller, after listening for a second longer, once more woke up, and briskly resuming her usual position tasted well and this time definitely rejected the butterfly. She then obstinately refused to taste *Papilio lyæus*, but recognized, accepted, and ate a *Pyrameis cardui*, though obviously without appetite, ignored an *Antanartia schœneia* for a few moments, but changing her mind tasted it and, evidently fully approving, crushed and swallowed it. She next similarly refused a yellow *Catopsilia florella* ♀, but then taking it from the forceps played with it for some seconds, as usual tossing it into the air and catching it, and finally crushed and swallowed it. She played similarly with a ♂ *Catopsilia florella* and an *Antanartia* but ended by dropping each, ignored, then accepted, crushed and swallowed a *Precis cebrene*, and after it the *Antanartia*, both with evident lack of appetite but no sign of dislike, crushed well and held, crushed again and held, then half swallowed but brought up again, crushed and held, and finally tossed aside a *Papilio hippocoön* (she very evidently lacked the space rather than the will), persistently ignored a *Catopsilia florella* ♂, and crushed and tossed carelessly away into the air a *Hamanumida dædalus*, afterwards refusing it, as also a

grasshopper, without tasting. Evidently, in so far as butterflies and Orthoptera were concerned, she was fairly replete. Nevertheless, on my offering her another large *Petascelis remipes* with a very strong smell, she accepted, crushed thoroughly (her peculiar manner in doing so reminding me of one's sensations in drinking a glass of particularly strong liqueur), and swallowed it, afterwards wiping her bill. I then offered a still larger though very similar bug, with, if anything, a still stronger smell and a quantity of bright blue matter exuding at the base of the thorax. The bird at once accepted it, and crushing it well, its breath once more almost taken away with the strength of its flavour, which it nevertheless obviously relished immensely, ate it. She then once more wiped her bill on the perch and refused obstinately to touch *Papilio hippocoon* or various favourite grasshoppers.

Ten minutes later she ignored *Catopsilia florella* ♂, just took in the point of her bill and tossed aside *Papilio lyæus*, *Papilio hippocoon*, and *Hamanumida dædalus*, and simply ignored various of her favourite grasshoppers.

Five minutes later she refused to touch *Papilio lyæus* and *Papilio hippocoon*.

Five minutes later she accepted, crushed and swallowed *Papilio lyæus* and two small grasshoppers, then refused without tasting a second *P. lyæus*, the *P. hippocoon*, and the *Catopsilia florella*, refused momentarily then accepted, crushed and swallowed *Hamanumida dædalus*, accepted, crushed very thoroughly and swallowed without hesitation the *hippocoon*, but repeatedly and with shakes of the head refused to have anything whatever to do with *Papilio lyæus* and the ♂ *Catopsilia*.

Three minutes later she readily ate the ♂ *Catopsilia*, tasted and rejected *Papilio lyæus*, readily ate a yellow ♀ *Catopsilia*, tasted and rejected a Lycoid Cetoniid (*Glycyphana balteata* var.), looking very bee-like with its wings spread (she did not crush into it at all—the beetle was hard—so I am doubtful whether it was properly tasted—no smell and no juices), and once more ate readily a ♂ and a yellow ♀ *Catopsilia*.

Twenty minutes later she crushed and readily ate *Papilio lyæus*, two small grasshoppers, and a second *Papilio lyæus*, tasted and at once rejected *Leuceronia thalassina* ♂ and *Papilio echerioides* ♀, accepted, crushed and held, then once more crushed and held, and finally rejected a *Papilio lyæus*.

I three times subsequently, at intervals of ten minutes, offered her *Papilio lyæus*, *Papilio echerioides* ♀, and *Leuceronia thalassina*, but she each time refused without tasting or just crushed them slightly and rejected them, without giving the slightest further indication as to their relative acceptability. The one indication that she had given points to *Papilio echerioides* ♀ being less acceptable than *Papilio lyæus* ♀, though not necessarily more so than *Leuceronia thalassina* ♂.

[SUMMARY:—

(1) *Grades*:—

- | | |
|-----------------------|--|
| | 1. Coreid bugs. |
| <i>P. cardui</i> . | { 2. <i>H. dædalus</i> , <i>P. cebrenæ</i> , a favourite grasshopper. |
| | { 3. <i>C. florella</i> ♂ and yellow ♀, <i>A. schæneia</i> , <i>P. hippocoon</i> . |
| <i>P. dardanus</i> ♂. | { 4. <i>P. lyæus</i> . |
| | { 5. <i>L. thalassina</i> ♂. } <i>P. echerioides</i> ♀, |
| <i>Glycyphana</i> | { 6. <i>E. dryope</i> . } <i>A. serena</i> 's pupa (on taste), <i>N. agatha</i> (?). |
| <i>balteata</i> . | { 7. <i>Syntomis cerbera</i> , <i>M. agathina</i> ♂, <i>Osprynchotus flavipes</i> , |
| | <i>Lygæus</i> , red beetle. |

I think that the experiment on the whole justifies the above order, though some placings are naturally lower than others. Nothing was eaten to quite the same point of repletion as in the Coreid bugs. Additionally, *M. agathina* was probably at any rate not better than *M. campina*, or this than *N. agatha*, or *E. dryope* and *L. thalassina* than *P. dardanus* ♂; *P. dardanus* ♂ was eaten apparently more readily than *P. lyæus* once, but perhaps in consequence of stimulative influence by the latter; *A. schæneia* was probably not better than *P. cardui*, or yellow *C. florella* than *A. schæneia* or *P. hippocoon*, or *P. lyæus* than the latter or *C. florella*. *P. hippocoon* seemed very near or equal to *C. florella* and *A. schæneia*.

(2) *Note at the time*: The various occupants of grade 7 "were evidently more obviously unpleasant than the pupa of *Acræa serena*. This was treated exactly similarly by the kingfisher (*Halcyon cyanooleucus*). In both cases it was obvious that the birds were not at all sure whether it was fit to eat (at that stage) or not, and it seemed as though they must almost possess some special gauging power at the back of the throat (*cf.* experiments on swallows, *passim*). *Neptis agatha* was eaten after twenty-four grasshoppers later, showing that each of the above insects was decidedly nearer the rejected *agathina* in degree of unpleasantness than to *agatha*, and the fact that *M. agathina* was played with—the roller being probably nearly hungry enough to eat it—just before she rejected the *Acræa* pupa shows the same. I tasted a little of the juice exuding from the pupa after its first rejection and it was not markedly unpleasant, as in the case of the larva and imago—a slight poppy flavour, I thought. The ichneumon has great tenacity of life. After its crushings by the birds and an additional sharp crushing of the thorax by myself, it quickly recovered and moved about in most lively fashion. *Lygæus swynnertoni* (found feeding in numbers on *Vernonia livingstoniana*) is much more easily killed. Its extreme unwelcomeness, in spite of its practical lack of smell, while the large strong-smelling Coreids were eaten with relish in preference to the most palatable butterflies and grasshoppers, shows that the more typical bug-smells are in no way an indication of unpleasantness to the roller. The Coreids are literally in swarms on the oranges near the forest, sucking their juices and blackening their surfaces with their numbers—a spot visited almost solely by bulbuls. On the trees being shaken they fly or, rather, drift off slowly in crowds, numbers landing on the ground just round about. They are common, too, on tender terminal shoots of coffee, conspicuously exposed on the surface and usually several together. They are very sluggish in their general habits."]

Exp. 73.—August 22. The bird was very hungry. She readily ate, after crushing each, a *Terias*, a *Mylothris rueppelli* (sex not noted), and a ♂ *M. agathina*, rejected an *Acræa johnstoni* and an *Acræa esebria* (fulvous ♂), also a ♀ *Mylothris agathina*. She then readily ate a ♂ *Mylothris agathina*, again rejected the ♀ and once more readily ate a ♂; tasted and rejected *Lygæus swynnertoni* and the ichneumon (of yesterday's species), readily ate another *Mylothris agathina* ♂, tasted and rejected *Acræa serena*, and readily ate a *Terias*.

I now gave her a smallish grasshopper, after which she readily ate another *Terias* but crushed and at once rejected a ♂ *Mylothris agathina*. Then followed two more grasshoppers and another *Terias*, three more grasshoppers and another *Terias*, five

more grasshoppers and yet another *Terias*, this one as readily as the rest. After six more grasshoppers she for some time refused to touch a *Terias senegalensis*, but finally, persuaded, took and swallowed it. Then two more grasshoppers, but I had evidently slightly overdone the feeding, for she now not only refused, then tasted, and rejected a *Terias*, but treated a *Belenois severina* exactly similarly.

Ten minutes later the bird readily ate the *Belenois* and refused the *Terias* most persistently without tasting. She then accepted doubtfully, crushed very slightly, and rejected a pupa of *Acræa buxtoni*.

Next, after eating a migratory locust, she persistently refused without tasting a second *Belenois*, but recognized and most readily ate a *Neptis agatha*.

After ten more small grasshoppers she obstinately refused to touch *Neptis agatha*, tasted doubtfully and rejected *Eurytela dryope*, refused without tasting *Leuceronia thalassina* ♂, crushed and readily ate a *Cyrestis camillus*, and after it the *Eurytela dryope* just rejected, refused to touch the *Neptis agatha*, but on my removing its wings crushed and definitely rejected it; crushed and readily ate *Eurytela hiarbas* and *Eurytela dryope*, tasted and rejected a wingless *Teracolus*, half-tasted, evidently viewing it with suspicion, a *Papilio angolanus* with one wing and refused to take it, then readily enough ate a *Eurytela dryope* and the *Papilio angolanus* with the wing removed.

After six more small grasshoppers she tasted and rejected emphatically both *Neptis agatha* and *Eurytela dryope*, refused to touch *Eurytela hiarbas* and readily ate *Papilio angolanus*, but also, immediately after it, the rejected *Eurytela dryope*.

Then two more grasshoppers and another *Eurytela dryope* and two more grasshoppers and yet another *Eurytela dryope*. After another four grasshoppers she crushed and rejected *Eurytela hiarbas* and *Eurytela dryope*, but ate the latter on its being reoffered, refusing, however, to have anything to do with the *Eurytela hiarbas*. The attendant had during the last few offerings been busying himself in distributing white ants to the various cages and the roller was unmistakably distracted in watching him. It seemed to me to account for this changeableness.

She now (the white ants having disappeared) readily ate a *Papilio angolanus* and a *Papilio demodocus*, crushed and rejected *Papilio angolanus*, refused persistently even to taste a wingless *Papilio echerioides* ♀, seeming to me to notice its very distinct bean-smell when brought close up, then crushed and rejected a *Papilio demodocus* and a *Papilio lyæus*, both ♀s. The latter was held in the bill longer and crushed more thoroughly, with an occasional pause, but it too was finally jerked away. She now refused persistently to again touch any of the four *Papilios*.

Fifteen minutes later, by lamplight, after at first ignoring them, she tasted all four in succession and at once rejected each.

Fifteen minutes later she crushed and ate the *Papilio demodocus* ♀ and the *Papilio angolanus*, refused, then tasted and rejected the *Papilio echerioides* ♀ (wingless), readily and without hesitation ate a *Papilio lyæus* (without wings and looking much like the *Papilio echerioides*), also a ♂ *Papilio demodocus*, crushed and rejected the *Papilio echerioides*, readily accepted and ate a wingless *Papilio lyæus*, and persistently refused without tasting and with signs of annoyance (shakes of head, retreating, etc.) the *Papilio echerioides*. She, I believe, recognized

it by its smell, for by that dim light it seemed impossible to distinguish it from *Papilio lyæus*.

Five minutes later she accepted without hesitation and ate a wingless *Papilio lyæus* and refused, then suspiciously half-tasted, and rejected the *Papilio echerioides*, retreating when I reoffered it.

Three minutes later she accepted without hesitation and ate a *Papilio lyæus*, crushed and rejected the *Papilio echerioides*, crushed and readily ate a wingless *P. demodocus*, and then simply settled down for the night, refusing *lyæus*, both with and without wings. Both sexes of *lyæus* were used in this experiment, but the *Papilio angolanus* were all ♂s.

[SUMMARY:—

- | | |
|--|------------------------------|
| 1. <i>P. lyæus</i> , on manner perhaps above | } <i>Cyrestis camillus</i> . |
| 2. <i>P. demodocus</i> . | |
| 3. <i>P. echerioides</i> ♀. | |

3. *E. dryope* and *E. hiarbas*.

4. *N. agatha*, *Teracolus* (?) ↓).

Pupa of <i>A. serena</i> .	{	5. <i>B. severina</i> , <i>Terias</i> .
		6. <i>Mylothris agathina</i> ♂.
		7. <i>A. esebria</i> ♂, <i>A. johnstoni</i> , <i>M. agathina</i> ♀, <i>Lygæus swynnertoni</i> , and <i>Osprynchotus flavipes</i> (<i>Terias</i> and <i>Bel. severina</i> also above <i>A. serena</i>).

E. hiarbas was probably not liked more than *E. dryope*, perhaps less.]

Exp. 74.—August 23. After eating from the forceps a number of grasshoppers the bird refused absolutely to touch a *Terias*, but readily accepted and ate a *Neptis agatha*.

After ten more grasshoppers she readily ate another *N. agatha*, but after seven more grasshoppers she refused to touch a third, readily ate *Eurytela hiarbas* and refused for some time, then, becoming doubtless slightly hungrier, accepted and ate the *Neptis agatha*.

After six more grasshoppers she refused repeatedly and most obstinately even to taste *Neptis agatha*, but readily ate a *Eurytela dryope*.

After three more grasshoppers she once more ate a *Eurytela dryope* and refused a *Neptis agatha*. She then ate a locust with wings removed and again ate *Eurytela dryope*; then another locust with wings removed and yet another *Eurytela dryope*. After a third locust, however, with wings removed, she persistently refused *Eurytela dryope* and *Papilio echerioides*, both without wings, crushed very thoroughly and half swallowed *Papilio angolanus*, but brought it up again and rejected it after some further crushing. She then tasted and at once rejected the same *Papilio angolanus* with its wings removed, but crushed very thoroughly and ate a wingless *Papilio demodocus* ♀, again tasted and rejected the *P. angolanus*, afterwards refusing without tasting *Papilio echerioides* ♀ and *Papilio lyæus* ♀ (wingless).

Fifteen minutes later she crushed and rejected the *Papilio angolanus*, refused, then tasted and rejected *Eurytela dryope*, refused without tasting *Papilio echerioides* ♀ and *Papilio lyæus*, wingless ♀, crushed at great length *Papilio lyæus* with

one wing attached and swallowed it, once more tasted and rejected *Papilio angolanus* and refused *Papilio echerioides* without tasting.

Thirty minutes later (by lamplight) she tasted and rejected the wingless *angolanus* ♂ and a *Eurytela dryope*, also a second ♂ *angolanus* with one wing, crushed and readily ate *Papilio lycæus* ♀, refused for some time, then tasted slightly and at once rejected the *Papilio echerioides* ♀, wingless.

Half an hour later she refused, then tasted and rejected *Papilio echerioides*, crushed and rejected *Eurytela dryope*, crushed and readily ate *Papilio angolanus* ♂, refused *Papilio echerioides* without tasting, crushed and rejected the next *Papilio angolanus* ♂ and a *Eurytela dryope*, but readily ate a *Papilio lycæus*. She then crushed and rejected both the *Papilio angolanus* and the *Papilio echerioides*, but readily ate, after crushing it, yesterday's white *Catopsilia*-like butterfly, still quite lively.

[SUMMARY :—

1. *Papilio lycæus* ♀, *Papilio demodocus* ♀, and the *Catopsilia*-like Pierine.
 2. *Papilio angolanus* ♂.
 3. *Eurytela dryope*, *Eurytela hiarbas*.
 4. *Neptis agatha*.
 5. *Terias*.
- P. echerioides* ♀. {

There was nothing to show whether the *Papilio echerioides* was more or less disliked than the two species of *Eurytela*.]

Exp. 75.—August 29. The bird refused a *Terias*, but on my continuing to hold it to her tasted it very slightly, as though merely to humour me, and drew back without tasting it. She then readily ate *Neptis agatha* and a migratory locust, crushed and at once rejected *Papilio angolanus* with all its wings, readily ate *Leuceronia argia* ♀ and *Eurytela dryope*, crushed and rejected *Papilio angolanus* with two wings, crushed doubtfully but finally threw back into her throat and swallowed one that I had stripped of wings, refused, then barely tasted and threw away the next, crushed and nearly swallowed a fifth, but, changing her mind, threw it away and shook her head and readily ate, after crushing it, a *Eurytela dryope*.

Three minutes later she crushed well with a doubtful air and swallowed a *Papilio angolanus* with one wing, refused the next for some time but finally took it from me with an air of irritation, crushed it slightly and threw it away (no wing), obstinately refused the next (with one wing), also the next, then tasted it very slightly and rejected it, after that persistently refusing to have anything to do with it.

She now ate a *Neptis agatha* with, I thought, disinclination, making as though to reject it, but changing her mind and tossing it carelessly back into her throat, refused, then tasted perfunctorily and rejected a *Terias*; refused for a moment, then accepted and readily enough ate a *Papilio lycæus*, readily accepted and ate a *Papilio demodocus*, refused a *Papilio angolanus*, then barely closed her bill on it and withdrew with a shake of the head and would have nothing further to do with it.

There was now a delay of, roughly, five minutes while I sallied out to catch a

Neptis agatha, of which there were several in the garden. It was readily accepted and eaten, as was also a *Papilio angolanus* with one wing. The next two *Papilio angolanus* were tasted and rejected (the first without wings, the second with two).

Again five minutes were spent in securing a *Neptis agatha*, and I gave the bird two small grasshoppers to make up for any increase of appetite that the delay might have caused. She then refused for a long time, without tasting, both *Neptis agatha* and wingless *Papilio angolanus*, but finally leant forward and cautiously tasting the tip of one of the latter's antennæ at once drew back with a shake of the head. She then crushed well and swallowed the *Neptis agatha* and tasted and rejected and afterwards refused obstinately to have anything to do with a *Papilio angolanus*.

She then battered and ate with enjoyment two large migratory locusts, refused even to touch *Neptis agatha* and *Papilio angolanus*, tasted and rejected *Eurytela dryope* and *Leuceronia argia* ♀, and refused without tasting *Papilio demodocus*.

Five minutes later she crushed and rejected *Leuceronia argia* ♀, crushed well and tossed away a *Papilio demodocus*, and refused persistently without tasting *Papilio lyæus*.

Five minutes later she refused without tasting *Leuceronia argia* ♀, *Papilio demodocus*, and *Papilio lyæus*.

Five minutes later again she readily ate *Papilio demodocus*, continued for a few minutes to refuse *Leuceronia argia* but finally accepted, crushed and ate it readily.

[SUMMARY:—(1) *Papilio angolanus* was placed much lower than on the 23rd, below *Neptis agatha* instead of above *Eurytela dryope*. "It will be interesting to see whether *Papilio echerioides* will still be placed below *angolanus*."

(2) Grades:—

- | | | |
|--------------------|---|---|
| <i>N. agatha</i> . | { | 1. <i>P. demodocus</i> , possibly on manner but not certainly above |
| <i>E. dryope</i> . | | 2. <i>L. argia</i> ♀. |
| | | 3. <i>P. angolanus</i> , above, one would judge, |
| | | 4. <i>Terias</i> , though this is not certain.] |

Exp. 76.—August 30. Hungry, refused to touch an *Acræa igola*, red ♀, with wings, tasted and at once rejected *Planema aganice* ♀ with one wing and an *Acræa anemosa* without, crushed very thoroughly and with a doubtful air a wingless *Danaïda chrysippus*, then threw it away; refused an *Acræa asema* with wings, refused, then half-tasted and rejected a *Nychitona medusa*, looked hard at an *Acræa johnstoni* with all its wings (doubtless suspicious of the *Acræa*-body), both from above and from below, then tasted and rejected it, refused persistently without tasting *Mylothris yulei* with one wing, refused for a moment, then tasted and rejected *Mylothris agathina* ♂, readily ate a *Terias*, refused *Mylothris agathina* ♂ once more without tasting, but readily ate another *Terias* and a *Papilio angolanus*.

I now gave her three small grasshoppers. After eating those she refused a *Terias*, crushed and rejected *P. angolanus*, refused, then changing her mind, crushed and ate the *Terias* (*T. senegalensis*), refused, then tasted and rejected *Papilio angolanus*, refused persistently a *Terias senegalensis*, recognized and eagerly accepted and ate a *Neptis agatha*, and once more refused obstinately without tasting the *Terias* and the *Papilio*.

Fifteen minutes later she refused but, changing her mind, ate *Papilio angolanus*, refused similarly and then ate a *Terias*, then (this time readily enough) ate another *Terias* and a second *Papilio angolanus*, two small grasshoppers, and yet another *Papilio angolanus*. I had, unfortunately, no *Terias* left to offer, but the experiment up to this point convinced me sufficiently that the bird regarded *Papilio angolanus* as on about the same level as *Terias*.

She then ate seven small grasshoppers, refused, then twice crushed and rejected *Neptis agatha*, tasted and rejected, but then changing her mind ate *Eurytela dryope* and, with apparent relish, after crushing it, *Papilio antheus*.

An interruption of twenty minutes now occurred. On my return the bird readily ate seven small grasshoppers and a *Neptis agatha*, a small and a large grasshopper, and another *Neptis agatha*. After seven more small grasshoppers, however, she refused obstinately and repeatedly to touch *Neptis agatha* or *Eurytela dryope*, crushed well and rejected *Papilio lyæus*, crushed and readily ate *Papilio antheus*, crushed and rejected, but on my reoffering it ate *Papilio lyæus*, listlessly, however, as though quite disinclined for food, refused the next without tasting, but, finally, yielding to my importunity, tasted and rejected it; obstinately refused *Papilio demodocus*, refused, then crushed and rejected *Papilio dardanus* ♂, and obstinately refused to touch either *Papilio antheus* or *Papilio lyæus*.

Five minutes later she refused to touch *Papilio lyæus*, *Papilio demodocus*, *Papilio antheus*, and *Papilio dardanus* ♂, but readily accepted and ate a *Catopsilia florella*, afterwards, her appetite doubtless stimulated by the eating of the Pierine, accepting and eating *Papilio lyæus* after much crushing and with evident disinclination. She then crushed slightly and tossed carelessly up into the air the ♂ *Papilio dardanus*, crushed very thoroughly and swallowed, though once more with disinclination, the *Papilio demodocus*, and refused persistently to touch *Papilio antheus*, *Papilio dardanus* ♂, *Papilio lyæus*, and *Catopsilia florella*.

Five minutes later she once more refused all four.

Five minutes later she readily enough ate *Catopsilia florella* and *Papilio antheus*, each as usual after crushing, refused, then accepted, crushed long and doubtfully, and finally ate *Papilio dardanus* ♂, refused obstinately to touch *Papilio lyæus*, half-tasted and refused to take *Papilio dardanus* ♂, and once more persistently refused without tasting *Papilio demodocus* and *Papilio lyæus*.

Three minutes later she crushed well and ate *Leuceronia argia* ♀ and refused without tasting *Papilio demodocus*, *Papilio lyæus*, *Leuceronia thalassina* ♀, and *Catopsilia florella*, but ate with disinclination one small grasshopper, refusing utterly to touch a second. The first was held for quite a long time in the point of the bill before being swallowed.

She then refused, but changing her mind tasted and, reassured, at once crushed well and swallowed *Salamis anacardii*, and after it, again after thorough crushing, *Papilio dardanus* ♀ f. *hippocoon*. She then crushed well and tossed away *Papilio antheus* and persistently refused without tasting *Salamis nebulosa*, *Salamis anacardii*, *Precis natalensis* ☉, *Pyrameis cardui*, and *Precis cebrene*, finally, however, changing her mind and eating the *Precis cebrene* and leaning forward to the *Pyrameis*, which I reoffered, but withdrawing without tasting it, evidently utterly replete. A second *Precis cebrene* was now persistently refused without tasting.

After a further interruption of nearly half an hour I continued the experiment by lantern-light. The bird now readily ate *Eurytela dryope*, *Neptis agatha*, *Syntomis cerbera*, and seven small grasshoppers, refused obstinately to touch *Neptis agatha*, crushed and rejected *Eurytela hiarbas*, refused *Eurytela dryope* without tasting, crushed and rejected *Leuceronia thalassina* ♀ and *Papilio lyceus*, barely closed her bill on *Papilio antheus* and refused to take it, refused without tasting *Salamis anacardii* and *Catopsilia florella*, refused, then tasted and, evidently attracted, crushed and ate *Precis natalensis* ♂ f., similarly refused, then crushed and ate *Precis archesia* ♂ f., accepted and ate without hesitation *Precis antilope*, refused for a time (probably taking it for *Eurytela dryope*), then tasted slightly and, reassured, readily ate *Precis elgiva*, refused obstinately without tasting *Precis tugela*, *Precis cebrene*, and *Pyrameis*, but, attracted by *Salamis nebulosa*, leaned forward, crushed and swallowed it, and after it three *Salamis anacardii* with the greatest relish. The last was held for some time before being swallowed, the bird being evidently replete. She now obstinately refused to touch *Precis cebrene* and *Pyrameis cardui*.

Five minutes later she refused to touch *Precis elgiva*, crushed slightly and tossed away *Precis tugela* and *Hamanumida dædalus*, and once more obstinately refused *Precis cebrene* and *Pyrameis cardui*.

Ten minutes later I reoffered all four of the above butterflies as also a *Precis archesia*, a brown *Crenis*, and a usually highly-acceptable grasshopper, but the bird simply ignored them. An hour later she readily ate *Eurytela dryope*, *Neptis agatha*, and a *Syntomis cerbera*, looking doubtful after the latter, however.

[SUMMARY:—(1) Note: “*Papilio angolanus* was roughly but unmistakably placed on a level with *Terias*, whether just below or just above it is impossible to be sure, but possibly the former. In either case the difference must be very small indeed. Both were once more definitely preferred to *Danaida*, various *Acræinæ*, *Leptosia*, and *Mylothris*, as was *Neptis agatha* to the *Terias* and the *Papilio*, and in their turn *Eurytela dryope* to the *Neptis* and *Papilio lyceus*, and *Papilio antheus* to the *Eurytela*. Between *Papilio lyceus*, *Papilio antheus*, *Papilio demodocus*, and *Papilio dardanus* ♂ there is, I believe, no great difference. *Leuceronia argia* ♀, as once or twice before, was taken up to a very late stage and in apparent equality to the pleasanter *Papilios* or even *C. florella*.”

(2) Grades:—

1. *Salamis* spp. 2.
- P. tugela*.
- P. natalensis* ♂ f.
- Pyr. cardui*.
- P. demodocus*.
- P. dardanus* ♂.
2. A favourite grasshopper, *P. cebrene*.
3. *C. florella*.
4. *P. antheus*.
5. *P. lyceus*.
6. *E. dryope*.
7. *N. agatha*.
8. *Terias*, *P. angolanus*.
9. *D. chrysippus*, on manner above
10. *A. igola*, red ♀, *P. aganice*,
- A. anemosa*.
- L. argia* ♀.
- L. thalassina* ♀
- and *E. hiarbas*? ↓.)
- A. asema*, *N. medusa*,
- A. johnstoni*, *M. yulei*,
- M. agathina* ♂.

P. dardanus ♀ f. *hippocoön* was placed in grade 1, but possibly as the result of special stimulation. Still it must be very high grade (unless, indeed, the eatings of *Syntomis* show that the lowest grades can take high places as the result of stimulation).

P. archesia ⊙ f., *P. antilope*, and *P. elgiva* were eaten up to *cebrene*-refusing point, but immediately after a *P. natalensis* ⊙ f., which may, of course, have stimulated.]

Exp. 77.—*August 31.* Hungry; refused with a shake of the head, evidently remembering it from last night, a *Syntomis cerbera*, but on my continuing to offer it tasted and rejected it. These moths are present in special numbers on the flowers of a *Vernonia podocoma* standing alone in the open pasture-land. Readily ate a *Terias*, crushed and rejected a second *Syntomid*, but readily enough ate a *Mylothris* (like *rueppelli*, but with paler orange), again tasted, this time slightly, another *Syntomis* and readily ate a ♂ *Mylothris agathina*, crushed and rejected a *Mylothris agathina* and a fourth *Syntomis*, refused absolutely to even touch a *Nychitona medusa*, crushed and at once rejected a blister beetle, *Mylabris*, in the act of exuding its yellow juices, and thereafter refused obstinately and with shakes of the head to taste it again.

She then eagerly ate two small grasshoppers, tasted and rejected, then refused to touch *Mylothris agathina* ♂, but readily ate a large pale *Terias*.

After two more small grasshoppers she readily ate a *Papilio angolanus* and after six more a second, this time after much more deliberate crushing; crushed and rejected, then refused without tasting, an *Aletis monteironis* with Myrmeleonid-like smell, came up eagerly but a little doubtfully to take a *Phymateus viridipes* with an unusually large supply of froth from behind the last pair of legs, but showed distinct suspicion of it on its suddenly displaying its brilliantly-coloured wings. She seized it, nevertheless, but the wings were greatly in her way and, after one or two ineffectual attempts to get into position for battering, she threw it away. I reoffered it, and this time the bird obtained a better grip, but after crushing it somewhat again rejected it. I now removed the wings and the bird crushed and battered it and seemed greatly inclined to eat it, but in the end once more abandoned it.

Twenty minutes later she twice refused, but then changing her mind crushed and readily ate a *Terias brigitta* (?), and crushed and rejected with marked dislike the *Aletis monteironis*.

She now suddenly flew down, seized the *Phymateus* that was moving about on the bottom of the cage, and returned with it to her usual perch, where she crushed and battered it to a thorough pulp, the abdomen coming off in the process. Finally, the thorax, after two or three ineffectual efforts, each followed by further battering, was swallowed, but the bird refused to have anything to say to the abdomen which I extracted and offered through the bars.

Three minutes later she accepted it, crushed it well, and twice nearly swallowed it, the second time getting it halfway down her throat. It was brought up again however, and rejected. On my twice reoffering it, it was each time taken and at

once flung away, and after that the bird obstinately refused to have anything to do with it. She then refused but, on my persisting, accepted, crushed, and rejected an *Ypthima*, accepting it, however, when reoffered and swallowing it doubtfully. She afterwards shook her head. *Neptis agatha* was, however, accepted eagerly and at once eaten.

The bird now ate eagerly three smallish grasshoppers and another *Neptis agatha*, followed by a somewhat large grasshopper, and then refused *Neptis agatha* persistently without tasting, readily ate *Eurytela dryope*, and again refused *Neptis agatha*, but ate *Eurytela hiarbas* and after it two *Neptis agatha*.

Ten minutes later she ate two grasshoppers, refused, but at once changing her mind accepted and ate *Neptis agatha*, three more grasshoppers, then refused *Neptis agatha* and *Neptis saclava*, but attracted by the latter's fluttering (the underside only was shown in order to distinguish it from *agatha*) afterwards accepted, crushed, and swallowed it.

After three more small grasshoppers she readily ate a *Neptis agatha*, after three more she refused to touch *Neptis agatha* but readily ate *Eurytela dryope*; after three more she again refused *Neptis agatha* but ate another *dryope*; after two more she once again refused *Neptis agatha*, tasted and rejected *Eurytela dryope*, but on my reoffering it ate it but refused *agatha*. She now ate two more grasshoppers, and finally and persistently refused to touch *Eurytela dryope* or *Papilio echerioides* ♀.

A delay of five minutes now occurred, after which (by lamplight) *Eurytela dryope* and *Papilio echerioides* ♀ were once more refused, *Charaxes ethalion* accepted and readily eaten, *Leuceronia thalassina* ♀ crushed and rejected, *Papilio antheus* ♀ crushed very thoroughly and eaten, *Papilio dardanus* and *Papilio demodocus* persistently refused without tasting, *Papilio lycæus* well crushed and rejected, but *Caprona pillaana* and a brown *Crenis* crushed and readily eaten. The bird now refused to touch *Papilio echerioides*, *Hamanumida dædalus*, *Precis cebrene*, *Catopsilia florella*, and *Pyrameis cardui*, simply settling down determinedly for the night. This refusal was repeated twenty minutes later.

[SUMMARY :—(1) *Grades* :—

<i>C. ethalion</i> .	{ 1. <i>Caprona pillaana</i> .	} <i>E. hiarbas</i> .
	2. <i>P. lycæus</i> and <i>P. antheus</i> .	
<i>P. dardanus</i> ♂.	{ 3. <i>E. dryope</i> .	}
<i>P. demodocus</i> .	4. <i>N. agatha</i> .	
<i>L. thalassina</i> ♀.	5. <i>Ypthima</i> , probably not much above <i>Phymateus</i> .	
<i>P. echerioides</i> ♀.		

Terias, probably not much or at all below *Phymateus*.

P. angolanus ? ↑.

6. <i>M. near rueppelli</i> and <i>M. agathina</i> ♂.	} <i>M. agathina</i> ♀, <i>N. medusa</i> , <i>Mylabris</i> , <i>Aletis monteironis</i> .
7. <i>Syntomis cerbera</i> .	

The *Crenis* was eaten (possibly under stimulation from the *Caprona*) up to *cebrene*-refusing point. I have placed *P. lycæus* and *P. antheus* over their two pleasanter congeners here simply on manner. The difference is probably slight.

(2) *Note*: "*Aletis monteironis* ♂, which from its slow flight, smell, and flaunting habits I had supposed to be probably very low-grade, proved actually to be so. The *Phymateus* was placed rather lower than on previous occasions (on a level with *Terias*?). The individual used had a large supply of froth that bubbled out freely from behind its posterior pair of legs. The smell is simply that of strong cocoa and not nearly so objectionable, from a human point of view, as that emitted by the dark dull blue *Phymateus*. *Papilio echerioides* (♀, the last one offered was a ♂, but only the underside was shown) was remembered with some dislike, *Papilio antheus* again appeared to be slightly preferred to *Papilio lyceus*, and *Caprona pillaana* was placed in 'grade 1' of the experiment."

Exp. 78.—September 1. Crushed and readily ate *Mylothris agathina* ♂, tasted and rejected *Acraea buxtoni* ♂, *Syntomis cerbera*, and *Acraea doubledayi* ♀. She then ate six small grasshoppers and refused to touch *Mylothris agathina* ♂ or a *Terias*. After six more small grasshoppers she again refused to touch *Terias*, but, after thorough crushing, ate a *Papilio angolanus* and, very readily, a *Belenois severina*, again crushing an *angolanus* well and swallowing it. After six more grasshoppers, she once more accepted and ate *Papilio angolanus* and obstinately refused to touch *Terias*; tasted slightly and rejected, then persistently refused *Mycalesis campina*, and obstinately refused the next *Papilio angolanus* as also *Neptis agatha*; refused, then changing her mind crushed *Papilio lyceus* well and swallowed it, tasted and rejected *Papilio angolanus* and refused *Eurytela dryope* absolutely.

Twenty minutes later she refused *Neptis agatha* without tasting, readily ate *Eurytela dryope*, refused *Neptis agatha* once more, readily ate *Papilio angolanus*, yet again refused *Neptis agatha* and *Mycalesis campina* without tasting, but, brisking up suddenly, crushed well and ate *Pseudacraea lucretia* and *Neptis agatha* and refused *Terias* without tasting. After two grasshoppers, she once more readily ate *Eurytela dryope*, crushed and rejected *Papilio angolanus*, readily ate, after tasting it well, ♀ *Papilio echerioides*, refused for a long time without tasting, but finally accepted and ate *Eurytela dryope*, tasted and rejected *Mycalesis campina*, and refused *Neptis agatha* without tasting, finally, however, accepting and eating it. She then ate six grasshoppers and *Eurytela dryope*, six more grasshoppers, and crushed and rejected *Eurytela dryope*, crushed well and ate *Leuceronia argia* ♀, refused without tasting *Eurytela dryope*, crushed very thoroughly and ate *Papilio dardanus* ♂, but rejected, after tasting it, the next; refused obstinately, without tasting them, *Papilio demodocus* ♀ and *Herpennia eriphia*, crushed well and rejected *Papilio lyceus*, refusing it on its being reoffered; crushed thoroughly and finally ate *Catopsilia florella*; refused *Precis elgiva* without tasting (taking it for *Eurytela dryope*?), crushed thoroughly and readily ate *Charaxes neanthes* and a *Zeritis*; tasted slightly and rejected *Herpennia eriphia*; refused, then crushed very thoroughly and ate a *Henotesia perspicua*, and readily ate a *Precis natalensis* ♂ f. She then refused obstinately to eat a *Precis clelia* and a *Precis cebrene*, crushed and ate two very small grasshoppers, holding each for a very long time before finally swallowing it and absolutely and repeatedly refused to touch another, or a *Precis cebrene* or *Pyrameis cardui*. A little later she once more refused grasshoppers, *Precis cebrene*, and *Pyrameis cardui*.

[SUMMARY:—

1. Small grasshoppers, above *Precis cebrene* and *P. clelia* and
∴ prob. above
2. *P. natalensis* ♂ f., *C. neanthes*, *Charaxes florella*.
3. *P. lyæus* in manner above
4. *P. dardanus* ♂ and, say, *P. demodocus* ♀, *L. argia* ♀.
5. *Eurytela dryope* and *Papilio echerioides* ♀, }
6. *P. angolanus* about here. } *P. lucretia*? ↑.
7. *Neptis agatha*, perhaps above
8. *Mycalesis campina*. *Terias*, *M. agathina* ♂, and (not above it)
A. serena, *S. cerbera*, and *A. doubledayi* ♀. *B. severina* was
placed above *Terias*.]

Exp. 79.—Several hours later—plenty of food meantime in cage—a *Terias* was persistently refused but a *Papilio angolanus* readily eaten. The bird then ate six small grasshoppers; refused, then tasted very slightly and rejected in turn *Belenois severina* and *Papilio angolanus*, obstinately refused *Terias* and a second *Papilio angolanus* without tasting, but readily ate *Neptis agatha*. Ten minutes later she tasted very slightly and rejected *Mycalesis campina*, and refused without tasting *Papilio angolanus*. In offering the latter insect I had brought it close up to the bird's bill, which it now grasped, crawling up over the roller's head. The bird shook it off, caught it as it fell, crushed it well, and rejected it. She then refused to touch *Belenois severina*. After four more grasshoppers, she tasted very slightly and refused to take *Neptis agatha*, but readily ate a *Eurytela dryope*, and after it she rejected *Neptis*. She then ate four more small grasshoppers, tasted and rejected *Neptis agatha*, *Eurytela dryope*, *Papilio echerioides* ♀, and *Herpenia eriphia*, but readily ate a ♂ *Leuceronia argia*, refused without tasting a *Pinacopteryx* (like ♂ *agathina*, but size of *yulei*), readily ate a ♂ *Papilio dardanus*, and tasted well and rejected the *Pinacopteryx*.

Fifteen minutes later she readily ate *Eurytela dryope* and *Neptis agatha*, a small grasshopper and one more *Neptis agatha*, three more grasshoppers, and a *Papilio angolanus*. After seven more grasshoppers, however, she tasted slightly and rejected *Neptis agatha*, readily ate a *Eurytela dryope*, refused without tasting *Neptis agatha*, crushed and readily ate the ♀ *Papilio echerioides* and immediately afterwards ate not only the hitherto rejected *Neptis agatha* and two *Papilio angolanus*, but a *Belenois severina* and, after refusing a *Terias*, quite a number of small grasshoppers. Fluctuations of appetite, the result usually of stimulation, are not infrequent, but a jump such as this, from pudding to soup, involving practically a recommencement of her nearly completed meal, was rather unprecedented.

In the evening, by lantern-light, she readily ate five small grasshoppers, crushed and rejected *Neptis agatha* and *Eurytela dryope*, and refused, then tasted slightly and rejected the *Pinacopteryx*, without wings. Five minutes later she crushed well and rejected with obvious dislike the *Pinacopteryx* (the body was now lost, so could not be reoffered), refused *Neptis agatha* without tasting, crushed and rejected *Eurytela dryope*, ate readily *Herpenia eriphia* (but it had previously fallen in water,

so tasting not necessarily trustworthy), and refused without tasting *Papilio demodocus*.

[SUMMARY :—

- | | |
|----------------------------|--|
| | 1. <i>Leuceronia argia</i> ♂, <i>Papilio dardanus</i> ♂. |
| <i>Herpennia eriphia</i> , | 2. <i>Eurytela dryope</i> , <i>P. echerioides</i> ♀. |
| <i>Pinacopteryx</i> , | 3. <i>Neptis agatha</i> . |
| | 4. <i>P. angolanus</i> , |
| | 5. <i>Terias</i> . |
- } *Belenois severina*.

If its tasting after falling in the water is to be relied on, *H. eriphia* would form a grade intermediate between the above grades 1 and 2.

The *Pinacopteryx* was, at any rate, probably not above *P. dardanus* ♂.]

Exp. 80.—September 2. Distinctly hungry, readily ate *Mylothris agathina* ♀, refused with many shakes of the head *Nychitona medusa*, tasted it and flung it away on my pressing it on her, tasted and rejected *Nyctemera leuconoë*, refused without tasting an *Aletis monteironis*, readily ate *Mylothris rueppelli* ♀, crushed thoroughly and finally rejected with evident dislike a ♀ of the common blue-and-yellow Ichneumon (*Osprynochotus flavipes*) that so often enters houses, crushed and after hesitation ate *Mylothris yulei* ♀, accepted the Ichneumon doubtfully and, after subjecting it to very prolonged crushing, half swallowed it, again crushed it thoroughly and ended by swallowing it finally, then crushed and rejected *Nyctemera leuconoë*, *Aletis monteironis* ♀, *Syntomis cerbera*, and *Planema aganice* ♀. She now, after five small grasshoppers, refused obstinately to touch *Terias senegalensis*, but readily ate a *Papilio angolanus* and a *Belenois severina*. After seven more grasshoppers it again refused to accept the *Terias*, but after crushing it well ate a *Papilio angolanus*. Then followed a grasshopper and another *Papilio angolanus*, a second grasshopper and again a *Papilio angolanus*, two more grasshoppers and three separate rejections after tasting of *Papilio angolanus*. *Belenois severina* was then refused persistently without tasting, a *Neptis agatha* barely tasted and rejected, a *Papilio angolanus* (one of the rejected ones) crushed rather doubtfully and eaten, a *Neptis agatha* refused, then definitely crushed and rejected, a *Belenois severina* tasted well and rejected, then refused persistently; a *Papilio angolanus* tasted and rejected but eaten on being reoffered and a *Neptis agatha* refused without tasting, but then tasted well and rejected. The bird now for a minute or two refused to touch *Papilio echerioides* ♂, then barely closed the point of her bill on it and refused to take it, again refused it without tasting, and finally accepted, crushed it well, and ate it without further hesitation. She then refused *Neptis agatha*, but changing her mind accepted and ate it, refused a second, but, once more changing her mind, ate it; refused repeatedly and emphatically to have anything to do with a *Belenois severina*, but readily ate a *Papilio angolanus*.

[SUMMARY :—

- (a) 1. *P. angolanus*.
2. *N. agatha*, *B. severina*, *T. senegalensis*.

- (b) 1. *Mylothris rueppelli* ♀.
 2. *Nychitona medusa*, *Nyctemera leuconoë*, *Aletis monteironis*, each probably not appreciably better than *M. agathina* ♀ or (with *Syntomis cerbera* and *Planema aganice* ♀) than *M. yulei* and *Osprynchotus flavipes*.
- (c) 1. *Mylothris yulei*.
 2. *O. flavipes*.

The following note is interesting as showing my impressions at the actual time of carrying out the above few experiments :—

Note at time : “The following represents my present idea of some of the roller’s preferences :—*Papilio antheus*; *Papilio lyceus* and *demodocus*; *Papilio dardanus* ♂; *Leuceronia argia*; *Leuceronia thalassina* ♂; *Papilio echerioides*; *Papilio angolanus* and *Eurytela dryope*; *Eurytela hiarbas*; *Neptis agatha*. The semicolons represent distinctions that are very small and all probably of about equal value. *Papilio angolanus* may, however, yet go higher; it is extraordinary that after having dropped in the roller’s estimation to the level of *Terias* it should have so quickly crept up to the neighbourhood of *Eurytela dryope*.”]

Exp. 81.—September 3. Crushed and rejected *Aletis monteironis*, *Syntomis cerbera*, *Acraea asema*, and *Danaida chrysippus*, but ate a *Terias* and, after a large number of small grasshoppers, persistently refused to touch *Neptis agatha* and *Eurytela dryope*.

Fifteen minutes later she tasted and rejected *Neptis agatha*, hesitated to taste a wingless *Papilio echerioides* ♂, looking bedraggled and macerated after its crushing by the Kingfisher, then barely closed her bill on it and withdrew with a shake of the head and refused even to taste *Eurytela dryope*.

Half an hour later, after four or five grasshoppers, she tasted and rejected the ♂ *Papilio echerioides*, readily ate *Neptis agatha*, and once more tasted and rejected the *Papilio echerioides*. She then ate ten small grasshoppers, the last with disinclination, and refused the next; tasted and at once rejected *Neptis agatha*, crushed well and threw away *Papilio demodocus* ♀, crushed and readily ate a *Papilio policles*, and refused a *Papilio lyceus*. On my continuing to hold it to her, however, she took it, crushed it for a long time, once or twice nearly rejecting it, but finally swallowed it. She then once more crushed and rejected *Papilio demodocus* ♀ and a second *Papilio lyceus*, but readily ate, after crushing each, *Salamis nebulosa*, *Salamis anacardii*, and *Papilio hippocoon*, then leant forward and half tasted *Papilio demodocus* ♀ but withdrew without taking it from the forceps. She then refused but, changing her mind, accepted and ate *Melanitis leda*, tasted very slightly and with suspicion and refused to take a *Henotesia perspicua*, refused persistently and with vehement shakes of the head a rather rubbed and battered *Precis elgiva*, which was perhaps taken for *Eurytela dryope*, but readily accepted and ate, though with obvious lack of appetite, *Precis archesia*, and similarly accepted, held for a time, and finally crushed and ate *Precis madagascariensis*.

Five minutes later she refused without tasting *Neptis agatha*, made as though to take but suddenly drew back from a *Rhopalocamptus forestan* (spots) without

smell. On my continuing to offer it she crushed it and threw it away, afterwards refusing persistently to touch it again. She then readily ate *Pyrameis cardui* and *Precis cebrene*, again tasted and rejected the *Rhopalocampta*, readily ate a *Pyrameis cardui* and a *Precis clelia*, refused the *Rhopalocampta* without tasting but, on my removing the wings, accepted it, still with some suspicion or disinclination, crushed it well and swallowed it. She then refused for a second but then accepted and ate *Precis cebrene*, refused *Precis elgiva* for a time with emphatic shakes of the head, undoubtedly taking it for *Eurytela dryope*, but finally tasted it cautiously and evidently approving of it accepted, crushed, swallowed it. She then refused *Precis cebrene*, grasshoppers, &c.

[SUMMARY:—

- (a) 1. *Terias*.
2. *A. monteironis*, *S. cerbera*, *A. asema*, *D. chrysippus*.
- (b) 1. *P. polices*, *S. nebulosa*, prob. *M. leda*, *P. archesia* ♂ f.

<i>H. perspicua</i> , <i>P. elgiva</i> (or what- ever it was taken for).	{	2. <i>P. demodocus</i> ♀, <i>P. lyceus</i> (latter, at any rate, prob. not better than <i>polices</i>). 3. <i>N. agatha</i> . 4. <i>P. echerioides</i> ♂.
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- (c) 1. *P. cardui*.
2. *N. agatha*, *Rh. forestan*.

P. cebrene, *P. clelia*, *R. forestan* itself, and *P. elgiva* were eaten to *cebrene*-refusing point, and *S. anacardii* and *P. hippocoon* in preference to *lyceus*, and *lyceus* in preference to *demodocus*, *cebrene* and *clelia* to *forestan*, but in all these cases, as in the eating of *P. madagascariensis* and of *P. elgiva*, special stimulation has to be suspected. Still *P. elgiva* and *P. madagascariensis* were both, in particular, eaten very high. The crushed state of the *P. echerioides* may have had to do with its rejection, but I do not feel sure that this is likely.]

Exp. 82.—September 7. Ate a very large grasshopper and a number of termites, then obstinately refused *Terias brigitta*, readily ate *Papilio angolanus* and *Neptis agatha*, and once more obstinately refused the *Terias*. She then ate six small grasshoppers, refused to touch the *Terias*, but again readily ate *Neptis agatha* and *Papilio angolanus*. After six more small grasshoppers she obstinately refused even to taste *Neptis agatha*, ate *Papilio angolanus* slowly and doubtfully or with disinclination, refused *Neptis agatha* and *Eurytela dryope*, crushed and rejected *Papilio angolanus*, and once more persistently refused *Eurytela dryope*.

Fifteen minutes later she refused, then tasted slightly and rejected *Neptis agatha*, readily ate *Papilio angolanus*, again refused to touch *Neptis agatha*, but crushed and ate *Papilio echerioides* ♂, *Eurytela dryope*, and, doubtfully, the *Neptis agatha* just refused; refused for a time, then tasted and rejected a *Terias* and readily ate a *Byblia*. After three small grasshoppers she tasted well and rejected *Neptis agatha*, crushed and readily ate a ♀ *Papilio echerioides*, again crushed and rejected *Neptis agatha*, readily ate a *Papilio angolanus*, but rejected the next after crushing it; tasted and rejected *Neptis agatha*, tasted and rejected a ♂ *Papilio echerioides*,

refused rather obstinately but finally crushed and rejected *Eurytela dryope*, refused, then crushed and readily ate *Leuceronia argia* ♀.

[SUMMARY:—

(1) *Note*: “This experiment appears to place *Papilio angolanus* and *Papilio echerioides* on roughly the same level, probably that of *Leuceronia thalassina*, that is to say if anything just above *Eurytela dryope* and just below *Leuceronia argia*. *P. echerioides* dead.”

(2) *Grades*:—

<i>Byblia</i> {	1. <i>L. argia</i> ♀.	} <i>E. dryope</i> .
	2. <i>P. angolanus</i> and <i>P. echerioides</i> ♂ & ♀.	
	3. <i>N. agatha</i> .	
	4. <i>T. brigitta</i> .]	

Exp. 83.—*September 8.* In morning, hungry, crushed and ate a freshly-caught *Acræa rabbaia*, tasted and rejected *Acræa* sp., crushed very thoroughly, nearly swallowed and finally rejected *Planema aganice* ♀, lively but rather long caught and juiceless. She then tasted a wingless *Danaida* and three times in succession rejected it with an air of suspicion. The *Acræa rabbaia* was unmistakably liked the best, and next to it came the *Planema*, showing that at all events without its “poppy” secretion, it is not obviously very violently unpleasant [wrong order for this deduction—though impression at time must count—and *aganice* incident perhaps due to stimulation by *rabbaia*].

Later in the day, once more fairly hungry, she hesitated over, then accepted, crushed, and swallowed a *Terias brigitta*, ate six or seven small grasshoppers, absolutely refused to touch either a *Terias brigitta* or a *Neptis agatha*, but readily ate a *Papilio angolanus*; ate three more grasshoppers and another *Papilio angolanus* and three more and a third *angolanus*. After the next three grasshoppers she absolutely refused to have anything to do with a *Papilio angolanus* and tasted and at once rejected *Papilio echerioides* ♂. Three minutes later she crushed and rejected *Papilio angolanus* and refused without tasting *Papilio echerioides* ♂; tasted and rejected *Eurytela dryope* and refused without tasting *Eurytela hiarbas*. Three minutes later she crushed well and ate with no sign of dislike a *Pinacopteryx saba*, crushed and ate a *Papilio angolanus*, refused, then tasted and rejected the ♂ *Papilio echerioides*; refused to touch a *Neptis agatha*, readily ate another *Papilio angolanus*, once more obstinately refused to taste a *Neptis agatha*, tasted and rejected *Eurytela hiarbas*, refused persistently without tasting *Eurytela dryope*, readily ate another *Papilio angolanus*, once more refused to have anything to do with *Neptis agatha* or ♂ *Papilio echerioides*, accepted suspiciously but having tasted it readily ate a *Henotesia perspicua*, two more grasshoppers and yet another *Papilio angolanus*. I was here interrupted.

Fifteen minutes later she readily ate six grasshoppers and a *Papilio angolanus*, refusing without tasting *Neptis agatha*. After three more grasshoppers she refused persistently without tasting *Neptis agatha*, *Eurytela dryope*, and *Papilio angolanus*. It struck me to get them definitely tasted by offering a very minute grasshopper or a small portion of a grasshopper between each. I therefore now gave the bird a very diminutive grasshopper from the well-known tin and then from the same

tin a *Papilio angolanus*. The bird was distinctly surprised at finding this in its bill instead of the expected grasshopper, but as it *was* there [or because of stimulation by the grasshopper] she proceeded to crush and swallow it. The next was a *Neptis agatha*, which was well crushed and rejected, and *Eurytela hiarbas*, which was similarly crushed but eaten, as was also a *Papilio angolanus*.

After three more small grasshoppers, *Papilio angolanus*, at first refused, was, after a minute grasshopper, crushed and definitely rejected, *Leuceronia argia* ♀ similarly crushed and thrown away, *Papilio demodocus* crushed and readily eaten, *Papilio dardanus* readily eaten, and *Papilio angolanus* and *Eurytela dryope* persistently refused without tasting. The bird then refused to touch a grasshopper nor would she look at any of a varied series of grasshoppers that I now offered her in turn. She also persistently refused without tasting *Papilio demodocus* ♂ and *Papilio antheus*; crushed and liking it readily ate a *Charaxes ethalion*, refused *Papilio demodocus*, ate after crushing it well *Papilio antheus*, and even more readily a second *Charaxes ethalion*; again refused *Papilio demodocus*, crushed well and ate *Papilio antheus*, and declined once more to have any dealings with *demodocus*, also however refusing without tasting *Precis archesia*, *Precis antilope*, a grasshopper, and *Precis cebrene*, being evidently nearly replete.

[SUMMARY :—

1. *C. ethalion*.
 2. *P. antheus*.
 3. *P. demodocus*.
- | | | | | |
|-----------------------|---|--|---|--|
| <i>L. argia</i>
♀. | { | 4. <i>P. angolanus</i> , <i>H. perspicua</i> .
5. <i>E. hiarbas</i> .
6. <i>N. agatha</i> and <i>Terias brigitta</i> . | } | <i>E. dryope</i> and
<i>P. echerioides</i> ♂. |
|-----------------------|---|--|---|--|

P. saba was probably placed at any rate not appreciably below *N. agatha* and *P. echerioides* ♂. It was probably stimulation by *C. ethalion* that caused *antheus* to be eaten right up to *cebrene*-refusing point, but *antheus* was in any case definitely preferred to *demodocus*.

A. rabbaix is likely to be amongst the pleasanter *Acræas*.]

Exp. 84.—September 9. There was food in the cage, but I fed the bird by hand on various Orthoptera till 'she' absolutely refused to touch another. She then crushed thoroughly and rejected *Papilio angolanus*, refused several different palatable grasshoppers, readily ate two *Charaxes candiope*, tasted and rejected *Papilio demodocus*, readily ate a *Charaxes pollux*, refused, then tasted slightly and rejected *Papilio demodocus*, refused without tasting *Salamis cacta* and *Pyrameis cardui*, then simply took in the point of her bill and dropped *Hypolimnas wahlbergi* and *Salamis cacta*, first looking at the former with some suspicion (its body and forewing no doubt reminded it of things unpleasant), and refused most obstinately to taste *Pyrameis cardui*. Three minutes later she refused persistently without tasting *Pyrameis cardui*, *Salamis cacta*, *Salamis anacardii*, *Hypolimnas wahlbergi*, and *Precis cebrene*.

Later in the day a second small experiment failed in its object. I fed the roller just too much, and all the above butterflies were once more persistently refused without tasting.

[SUMMARY :—

- (a) 1. *C. pollux* (and *H. wahlbergi*, *S. cacta*, *P. cardui*, *P. cebrene*, *S. anacardii* apparently not preferred to it).
 2. *P. demodocus*, *P. angolanus*, various favourite grasshoppers.

C. candiope was also preferred to *P. angolanus* and the grasshoppers.]

Exp. 85.—*September 10.* Fed the roller on various Orthoptera, &c., till she would eat no more. She then refused but went on to taste and reject *Papilio demodocus* and *Papilio angolanus*, just took *Hypolimnas wahlbergi* listlessly in the tip of her bill and dropped it, also *Precis cebrene*, and refused without tasting *Pyrameis cardui*, *Precis natalensis* ☉ f., *Salamis anacardii*, and *Salamis cacta*. After an interval she refused without tasting *Papilio demodocus*, *Euralia wahlbergi*, and *Salamis cacta*, crushed and readily ate a mimetic *Baoris* and a Lycaenid (probably *Zeritis* of outskirts), but then went on to eat also *Papilio demodocus* and *Eurytela dryope*, rejecting at once however after she had tasted it *Neptis agatha*. I decided not to reoffer the two main butterflies of the experiment as the bird was too hungry once more and I had given away such grasshoppers as remained. The *Salamis cacta* was in any case now dead.

[Probable that the *Baoris* was preferred to *P. demodocus* and, if she really knew them, to *H. wahlbergi* and *S. cacta*. The *Zeritis*, eaten after stimulation, was not necessarily better liked than the *E. dryope*.]

Exp. 86.—*September 11.* Had just been feeding and had returned to her usual perch presumably satisfied, leaving a number of very favourite insects uneaten. She then refused obstinately to touch *Mylothris rueppelli* or a *Terias*, but readily accepted and ate *Neptis agatha*, most readily accepted a number of grasshoppers by hand, including those she had abandoned, and finally absolutely refused to touch either another grasshopper, *Neptis agatha*, *Papilio lyceus*, or *Papilio demodocus*. Three minutes later she tasted and rejected *Papilio lyceus* and *Papilio demodocus*, looked very suspiciously at both *Euxanthe wakefieldi* and *Hypolimnas wahlbergi*, both wingless, the bodies in each case being very reminiscent of *Danainæ*, then took each in a gingerly manner in the tip of her bill and dropped it, I believe quite without tasting, readily accepted and ate *Precis natalensis* ☉ f., *Papilio policeses*, *Papilio antheus*, and *Papilio hippocoon* (each with one wing), doubtfully refused without tasting *Euxanthe wakefieldi* and *Hypolimnas wahlbergi*, readily ate *Papilio hippocoon* and *Precis archesia*, refused without tasting *Papilio demodocus* and *Papilio lyceus*, but readily accepted and ate *Papilio hippocoon*, *Precis natalensis* ☉, and *Precis archesia*. She then refused *Precis natalensis*, *Papilio hippocoon*, and *Euxanthe wakefieldi*, crushed slightly in the point of its bill and dropped *Precis cebrene*, accepted and ate *Salamis anacardii* and *Salamis nebulosa*, but refused the next as also several of the preceding butterflies reoffered.

Later she readily ate *Papilio angolanus* and three small grasshoppers, refused without tasting the next *Papilio angolanus*, also *Papilio lyceus* and *Papilio demodocus*, tasted and rejected *Euxanthe wakefieldi* and refused without tasting *Precis archesia*. It was obvious that the bird found the thorax of the *Euxanthe*

unusually tough and though she gave it a sufficient squeeze to have crushed the average butterfly there was no evidence afterwards on the thorax itself of its having done so. Not five minutes later she again crushed and rejected *Euxanthe wakefieldi* and refused *Papilio lyæus* without tasting.

Five minutes later she readily ate *Papilio lyæus*, crushed very thoroughly and appeared greatly inclined to swallow *Euxanthe wakefieldi* but in the end rejected it, refused without tasting *Papilio demodocus*, tasted and rejected *Papilio lyæus*, readily accepted and after thorough crushing ate a *Papilio demodocus*, tasted and rejected *Neptis agatha* and refused without tasting *Euxanthe wakefieldi* and *Precis archesia* (wingless). Three minutes later she subjected to very thorough and very prolonged crushing *Euxanthe wakefieldi*, during which she twice nearly swallowed it, but each time brought it forward into the bill again and subjected it to renewed crushing. Finally she rejected it with a certain amount of hesitation.

I now offered a particularly large *Neptis agatha* which was accepted, but, on being tasted, at once and emphatically flung it away. The bird then readily ate a *Papilio lyæus* and refused without tasting the *Neptis agatha* and a *Papilio angolanus*. Two minutes later she barely tasted, then dropped *Euxanthe wakefieldi*; five minutes later she tasted and rejected *Papilio angolanus*, just took in its bill and dropped *Euxanthe wakefieldi*, readily enough ate a *Papilio lyæus*, crushed very thoroughly and swallowed with no sign of dislike *Euxanthe wakefieldi*, tasted and at once rejected *Papilio angolanus*, readily ate a *Papilio lyæus*, after it the *angolanus* reoffered; crushed and rejected the next *Papilio angolanus*, readily ate a *Papilio lyæus*, and refused persistently without tasting a *Papilio hippocoon*, a *Precis cebrene*, a *Papilio lyæus*, and a *Neptis agatha*.

[SUMMARY:—

- | | | |
|---------------------|--|-------------------------|
| | 1. <i>Salamis nebulosa</i> (and, if not the result of stimulation, <i>Salamis anarcardi</i>). | |
| | 2. <i>Precis natalensis</i> ♂ f., <i>P. dardanus</i> ♀ f. <i>hippocoon</i> (and, if not the result of special stimulation, <i>P. antheus</i> , <i>P. policeses</i> , and <i>Precis archesia</i>). | |
| <i>P. cebrene</i> . | 3. <i>Papilio lyæus</i> and <i>P. demodocus</i> . | } <i>H. wahlbergi</i> . |
| | 4. <i>Euxanthe wakefieldi</i> and probably <i>P. angolanus</i> . | |
| | 5. <i>Neptis agatha</i> . | |
| | 6. <i>Terias</i> and <i>M. rueppelli</i> . | |

Note at the time: "I had unfortunately no *Eurytela dryope* to offer with the *Euxanthe wakefieldi*, but am certain that the latter was not more distasteful to the roller than is *Papilio angolanus*, which nowadays roughly equals *Eurytela dryope*; possibly less, for there could be no doubt at all that the bird suspected both its appearance* and the toughness of its thorax and so probably tended to place it lower than its actual taste warranted. It appeared to be disliked (or suspected?) distinctly more than *Papilio lyæus* and very distinctly less than *Neptis agatha*."

* White-spotted thorax and body, which both in its bulging shape and in the yellow colour of its fluff is highly reminiscent of *Amauris dominicanus*. The latter often has yellowish areas due to *bareness*.

Exp. 87.—*September 12.* Very hungry; tasted cautiously and promptly rejected, wiping her bill and showing every sign of the greatest disgust, a brilliant red adult "velvet mite" (*Trombidium* sp.) from Chirinda (it tasted intensely of *Amauris*-cum-quinine), crushed and rejected *Acræa asema*, readily ate a *Terias* and a wingless *Danaida chrysippus*, crushed well and very nearly swallowed but brought up and threw away *Acræa rahira*, crushed well and readily ate a wingless *Danaida*, crushed and rejected *Acræa rahira* with some hesitation and *Acræa anemosa* with promptitude.

A few minutes later I again offered her a *Danaida* which she for some time refused with emphatic shakes of the head but finally tasted. She at once rejected it, shaking her head and wiping her bill. This *Danaida* was in no way abnormal in the matter of smell and it seemed probable that the two preceding ones, perhaps not recognised without wings, had disagreed with the bird. The *Acræa rahira* was distinctly less disliked than either *Acræa asema* or *Acræa anemosa*, though more so than *Terias* or *Danaida*.

I now fed the bird on grasshoppers till she would eat no more. She then crushed and rejected *Papilio angolanus*, *Papilio trophonius* (v. above), and *Papilio dardanus* ♂. Five minutes later she readily ate a *Catopsilia florella* and a *Papilio dardanus* ♂, tasted and rejected the *trophonius*, readily ate a *Precis artaxia*, and again rejected the *trophonius*. Five minutes later she refused to touch the *trophonius*, but readily ate a *Precis natalensis* ♂ f. and again refused *trophonius*. Five minutes later she refused *trophonius*, readily ate after crushing it *P. angolanus*, refused *trophonius*, tasted and rejected *angolanus*, refused *trophonius*, and readily accepted and ate *Precis archesia*. She then twice hesitatingly tasted (once by a leg, once by an antenna) the *Papilio trophonius* and refused it; again readily accepted and ate a *Precis archesia*, refused *trophonius*, crushed and ate *P. angolanus* and again refused *trophonius* and *Neptis agatha*.

[SUMMARY:—

<i>Terias</i> .	{	1. <i>Precis archesia</i> .	}	<i>Precis natalensis</i> ♂ f.
		2. <i>P. angolanus</i> .		
		3. <i>D. chrysippus</i> .		
		4. <i>A. rahira</i> .		
		5. <i>A. asema</i> , <i>A. anemosa</i> .		
		6. <i>Trombidium</i> sp. (on manner).		
				<i>P. dardanus</i> ♀ f. <i>trophonius</i> (refusal probably due mainly to suspicion of coloration).

The tendency to try the *trophonius* was interesting, and suggested that it might require less to overcome suspicion of an imperfect mimic than of the model.]

Exp. 88.—*September 23.* Ate several grasshoppers; refused persistently to taste a *Terias*, and crushed and very promptly rejected a *Mycalesis campina*, readily ate *Neptis agatha* and *Eurytela dryope*, but after a few more grasshoppers rejected *Neptis agatha*.

I was interrupted here, but later the bird refused absolutely to touch *Terias*, shaking her head each time I offered it, refused for a moment, then, changing her mind, accepted and readily ate a *Neptis agatha*, refused persistently and with violent shakes of the head to have anything to do with a *Mycalesis campina*, ate readily

four small grasshoppers, and after distinct hesitation and much crushing a *Papilio angolanus*, barely tasted the antenna of a *Papilio echerioides* ♂, and refused to have anything further to do with it; refused without tasting most persistently a *Papilio angolanus* and a *Papilio demodocus*, readily accepted and ate a *Precis natalensis* ♀ f., again refused to touch a *Papilio angolanus*, and tasted very slightly and rejected a *Papilio echerioides* ♂.

[SUMMARY:—

- (a) 1. *N. agatha*, bitter grasshoppers (and *E. dryope* and *P. angolanus*?), ? *Terias*, and *Myc. campina*.
- (b) 1. *P. natalensis* ♀ f.
- 2. *P. angolanus*, *P. demodocus*, *P. echerioides* ♂.]

Exp. 89.—September 24. Ate a number of grasshoppers, then readily a *Papilio demodocus*, a *Neptis agatha*, and several more grasshoppers. She then refused absolutely to eat any more of the latter, crushed and threw away a *Papilio demodocus*, crushed at great length a flower-haunting mantis (*Pseudocreobotra wahlbergi*), then remained holding it as though replete but not liking to part with it, finally again crushed it well and tossed it aside, rejecting in the same way *Papilio polices* and *Precis natalensis* ♀ f. Five minutes later she once more accepted each with disinclination and threw it away. Five minutes later she refused the Mantis and *Papilio polices*, tasted and rejected *Papilio demodocus*, crushed well and ate with apparent relish the mantis and refused persistently without tasting *Papilio demodocus*, *Papilio polices*, *Papilio lyæus*, and *Charaxes candiope*.

There could be no doubt that the bird placed the mantis very high, enjoying it thoroughly in spite of the fact that it haunts flowers most conspicuously. [It is probably not lower than *Papilio polices*, possibly higher, even perhaps as high as *Charaxes*.]

Exp. 90.—September 28. Hungry; readily ate a *Terias*. I now placed a handful of Orthoptera in the cage, and the bird at once descended, ate a number of them (which it appeared to pick up at random apart from the usual preference for the larger spp. on commencing to feed), and retired to a high perch presumably satisfied. She then nevertheless ate not only a *Neptis agatha* and a *Mycalesis campina*, but a *Terias brigitta*. After six more grasshoppers given by hand she again readily accepted and ate a *Neptis agatha* and a *Mycalesis campina*, but persistently refused, with shakes of the head, to touch a *Terias*.

After six more grasshoppers she for some time refused to touch another, although I offered her several favourite species in turn. At last, however, she accepted one and once more refused all I offered, then ate another, and finally and most persistently refused to have anything to do with any others. On my now giving her a *Precis natalensis* ♀ f., she just took it in the point of her bill and tossed it aside, but, attracted by the struggles of a *Papilio lyæus*, definitely crushed this and flung it away. She then refused but, changing her mind, accepted and ate with apparent relish *Salamis cacta* and the *Precis natalensis* ♀ f. which I reoffered,

refused to touch a *Precis madagascariensis*, but recognised with evident pleasure and accepted and ate a second *Precis natalensis* ♂ f. She then accepted a *Charaxes pollux*, crushed it well and held it in her bill for two or three minutes, being evidently loath to relinquish it, yet feeling that she could not find space for it. Finally she dropped it. She then refused a *Charaxes candiope*, but in the end, attracted by its violent fluttering, accepted and ate it; took in her bill and dropped through sheer repletion a *Charaxes pollux*, a *Charaxes cithæron*, and a small queer termite, and refused persistently even to taste a very favourite grasshopper.

I reoffered all four insects three times at intervals of ten minutes, but they were each time ignored.

[SUMMARY :—

- | | |
|-------------------|--|
| | 1. <i>Salamis cacta</i> var. <i>languida</i> . |
| Higher grade | 2. <i>Precis natalensis</i> ♂ f. (to <i>Charaxes</i> -refusal point). |
| grasshoppers. | 3. <i>Precis orithyia</i> var. <i>madagascariensis</i> . <i>Terias</i> (not higher |
| <i>P. lyæus</i> . | apparently than <i>N. agatha</i> and <i>M. campina</i>).] |

Exp. 91.—September 30. Fed with grasshoppers till she would absolutely not touch another. She then most obstinately refused to taste *Papilio angolanus*, accepted *Papilio demodocus*, subjected it to very prolonged crushing, being quite evidently doubtful whether to swallow it, but finally did so; readily ate a *Charaxes brutus*, obstinately refused to have anything to do with a *Papilio demodocus* and a *Papilio lyæus*; crushed and readily ate a *Charaxes pollux*; again refused to touch *Papilio demodocus*, *Papilio angolanus*, and *Papilio lyæus*; readily ate a second *Charaxes pollux*; held for some time and finally dropped a *Precis artaxia*; refused, then accepted and ate with relish a large moth, *Nyctipao macrops*, refused without tasting *Precis artaxia*; crushed, held, and finally swallowed *Charaxes candiope*. She was evidently nearly replete. Three minutes later I reoffered the *Precis artaxia*, which was this time eaten readily, while *Papilio lyæus*, *Papilio demodocus*, *Papilio policeses*, and *Papilio angolanus* were obstinately refused without tasting, and *Leuceronia thalassina* tasted and rejected.

[SUMMARY:—Assuming the three large species of *Charaxes* to be of the same grade we have

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|---------------------|---|
| | 1. <i>C. brutus</i> , <i>C. pollux</i> , <i>C. candiope</i> , <i>Nyctipao macrops</i> . |
| | 2. <i>Precis artaxia</i> . |
| <i>Pap. lyæus</i> . | 3. <i>Pap. demodocus</i> . |
| | 4. <i>P. angolanus</i> ; grasshoppers. |

It is probable that *P. artaxia* was also preferred to *P. policeses* and *L. thalassina*, though the offerings were in the wrong order to render this certain.]

Exp. 92.—October 10. I offered the roller (hungry) a section of a smallish "night-adder," about $1\frac{1}{2}$ in. long. Usually a quite imperturbable bird, she now at once dashed to the back of the cage with great fright and scurry of wings, but, gradually recovering herself, returned to her usual perch and after very slight hesitation accepted the piece, crushed it once or twice, and threw it away. I reoffered it three times and she each time did the same, evidently not sure

whether she cared for it or not. The next time, however, she swallowed it (a fairly thick piece). I then cut out and offered a small scrap of the snake's flesh without skin. This she tasted very deliberately and rejected, but she ate it on its being reoffered. The next piece she again tasted and rejected, and thenceforth would have nothing to do with it, refusing it most obstinately. She very readily, however, ate a *Neptis agatha* and a *Terias senegalensis* (I had unfortunately nothing more unpleasant than the latter to offer, but the bird was still distinctly hungry), followed by four smallish grasshoppers. She then refused utterly with shakes of the head to touch the small piece of snake-flesh, but readily accepted and ate another *Terias*, once more persistently refusing the piece of snake.

A little later, after several more grasshoppers, she refused a *Terias* but eagerly accepted and ate a *Neptis agatha*, *Mycalesis campina* ♂ and ♀, and the *Terias* reoffered. After ten more grasshoppers she refused repeatedly and obstinately to touch a *Terias*, but most readily accepted and ate a *Neptis agatha*.

[SUMMARY :—

1. *N. agatha* (*M. campina* perhaps the result of stimulation).
2. *Terias senegalensis*.
3. Night-adder.

The fear shown by an occasional snake-eater at the unexpected appearance of a bit of snake was interesting.]

Exp. 93.—October 12. The bird was obviously hungry. She crushed well, hesitated for a few seconds over, then threw right away a ♂ *Lampyris marginipennis*, readily accepted and ate *Terias senegalensis*, twice refused but, changing her mind, the result doubtless of her hunger, accepted, crushed lightly, and at once threw away a second *Lampyris*, crushed and readily ate a *Mylothris yulei*, but again tasted and rejected the *Lampyris*, as also *Amauris dominicanus*.

She then ate four small pieces of fresh meat (lamb) and refused the next, but though coaxed into eating it flatly and finally refused to have anything to do with the next. She refused equally obstinately to touch a *Terias*, but readily accepted and ate a *Mycalesis campina*, afterwards once more refusing the *Terias*. I then gave her six grasshoppers, after which she fairly readily ate another *Mycalesis campina*, then crushed well and finally flung away a wood-boring longicorn, *Ceroplesis caffer*, of which I had removed one elytron, afterwards utterly and obstinately refused to have anything further to do with it. The beetle in question smelt slightly of sandal-wood and a clear white liquid exuded when the elytron was removed.

Ten minutes later she tasted and at once flung away a small piece of lamb's meat, ate eleven small grasshoppers and refused utterly to touch another; crushed and rejected *Papilio angolanus*, refused for a second then crushed and very readily ate an *Arrugia basuta* ♀, tasted and rejected *Papilio lycaeus*; refused for a second, undoubtedly through disinclination, then accepted and readily ate a ♂ *Arrugia basuta*, refused without tasting *Hypolimnas wahlbergi* and for a second *Precis artaxia*, but then, changing her mind, accepted and ate the latter; accepted *H. wahlbergi* with a little hesitation, but having tasted it appeared quite reassured

and crushed and swallowed it; held *Precis natalensis* ♂ f. a good many seconds before crushing and swallowing it; played with *Catacroptera cloantha* and *Hamanimida dædalus*, tossing them up into the air and catching them and finally letting each drop, refused *Precis cebrene*, but, changing her mind, accepted it, held it in her bill for a time and finally crushed and swallowed it, and refused without tasting *Hamanimida dædalus*, *Catacroptera cloantha*, and *Precis cebrene*. Five minutes later she refused to touch a ♀ termite or any grasshoppers, but accepted and ate *Catacroptera cloantha*, *Hamanimida dædalus*, *Precis cebrene*, and *Catopsilia florella*, holding each for some time before swallowing it; refused, then tossed up into the air a ♂ *Arrugia basuta*, a *Precis artaxia*, *Precis natalensis* ♂ f., and *Precis cebrene*. Five minutes later again and once more ten minutes after that she refused to taste any of them nor would she touch a ♀ termite nor any of the various grasshoppers offered her.

[SUMMARY :—

<i>M. campina</i> .	{	1. <i>P. cebrene</i> , perhaps slightly over	{	<i>A. basuta</i> ♂ and ♀, <i>P. artaxia</i> , perhaps
		2. <i>C. cloantha</i> and <i>H. dædalus</i> .		<i>C. florella</i> , probably <i>H. wahlbergi</i> and <i>P. natalensis</i> ♂ f.
<i>P. lyæus</i> .	{	3. Favourite grasshoppers.	{	
<i>C. caffer</i> .		4. <i>T. senegalensis</i> , <i>M. yulei</i> , lamb.		
Termite.		5. <i>Lampyrus marginepennis</i> ♂ and probably <i>Amauris dominicanus</i> .		

“The roller was in excellent, emphatic form.”]

Exp. 94.—October 13. After a number of grasshoppers the bird readily ate *Papilio angolanus*, four more grasshoppers, *Papilio lyæus*, and *Charaxes brutus*, then refused obstinately to touch a second *Papilio lyæus* or *Papilio leonidas* (with one forewing attached to distinguish it more clearly from *Papilio angolanus* which had had a hindwing). Five minutes later she crushed and rejected *Papilio leonidas*, readily ate a *Precis artaxia*, and crushed and rejected *Papilio lyæus*, thus placing *Papilio leonidas* below *Precis artaxia*, *P. lyæus* not above it, and *P. leonidas* and *P. lyæus* each probably not above *C. brutus*.

Exp. 95.—October 14. Readily ate in the morning several grasshoppers and a *Mycalesis campina*, crushed thoroughly (with distinct difficulty at first in retaining her grip on it owing to the hard polished surface of its elytra) and ate without sign of dislike a black and white Cetoniid, then several more grasshoppers and a *Mycalesis campina*. I then fed her on grasshoppers, crickets, etc., till she absolutely and persistently refused to touch another, though I passed several very favourite species in review before her.

She then refused without tasting *Papilio angolanus*, tasted and rejected *Papilio leonidas*, and, but with apparent disinclination, a *Papilio lyæus*, refused, then tasted and flung right away the *Papilio angolanus* and once more tasted, this time slightly, and threw aside the *Papilio leonidas*. Five minutes later she crushed and once more rejected the *Papilio leonidas* and persistently refused even to taste *Papilio angolanus*. Fifteen minutes later she crushed and rejected each. Ten minutes later again she once more crushed and rejected each. Twenty minutes

later she readily ate a *Papilio angolanus*, a *Mycalesis campina*, and four small grasshoppers, after which she once again refused to touch another; refused, then tasted and rejected *Papilio leonidas*, and refused without tasting *Papilio angolanus*.

Ten minutes later she obstinately ignored both, also grasshoppers.

[SUMMARY:—

1. *P. lycæus*.
2. *P. leonidas* and *P. angolanus*, and grasshoppers. *P. leonidas* not above *P. angolanus*.

Note ability to reduce black and white Cetoniid.]

I was short of butterflies for the experiment, but in the late afternoon, two *Neptis agatha* having come in in the meantime, I again gave her by hand a number of grasshoppers, after which she readily ate a *Mycalesis campina*, four more grasshoppers, and a *Neptis agatha*, six more grasshoppers, and a second *Neptis agatha*. I now, rather expecting a rejection, offered her the same species of Cetoniid that she had already eaten in the morning. A moment afterwards I regretted doing so, for it was eaten after the usual crushing and being a comparatively bulky article of diet carried the bird a stage too far and caused her to now refuse *Papilio leonidas* and *Papilio angolanus* without tasting. Four or five times subsequently by lantern-light at about ten-minute intervals I offered the two species of *Papilio*, but the bird had settled down for the night and absolutely refused to touch them.

The *Papilio leonidas* was already dead in the above experiment, but having been kept on damp earth was still perfectly fresh and supple. It was, at any rate, not appreciably preferred to the Cetoniid, which was once more reduced.

Exp. 97.—October 20. Hungry; crushed and rejected a ♀ *Aletis monteironis*, *Acræa satís* ♂ and a spotted Hypsid moth, *Argina amanda*, accepted most readily and ate a *Terias brigitta*, and tasted and rejected an *Acræa asema*.

Later in the day, to test the probable value of the resemblance between *Charaxes brutus* and *Papilio echerioides* ♂, I carried out the following experiment, at the same time experimenting on *Pycnonotus layardi* (B) with model and mimic reversed. I first fed the roller up on various Orthoptera (including migratory locusts, crickets, locustids, and small grasshoppers of various kinds) until she absolutely refused to touch another.

I then offered her a ♂ *Papilio echerioides* with upper surface of wings fully displayed. She took it by the base of one of the forewings, crushed it there and threw it away, refusing to have anything to do with it on my reoffering it. I then offered instead *Charaxes brutus*, its upper surface similarly displayed. The roller refused to have anything to do with it. On my closing its wings, however, and reoffering it, this time of course with only the narrowly-barred under surface showing, the bird seized it with actual eagerness, crushed it well, and swallowed it with evident relish. The wings were not removed and as the insect was brought into final position for swallowing, head first, they projected prominently on each side of the bill with their upper surface vividly displayed so that the bird could not have failed to take note of it. That she had done so was proved by the fact that on my now offering a second *Papilio echerioides* ♂ with the upper surface once

more exhibited, the bird edged towards it with a somewhat doubtful air, took it from the forceps but then at once threw it right away in disgust, afterwards ignoring a second *Charaxes brutus*, offered with the upper surface towards her.

[It was evident from this experiment that for a bird in the appropriate stages of repletion *Papilio echerioides* is capable of acting most effectively as a model for *Charaxes brutus*.

Preferences: *T. briggata* was preferred to *A. monteironis*, *A. satis* ♂, and *Argina amanda*, and at any rate probably not less than *A. asema*.]

Exp. 98.—October 21. After several grasshoppers the bird ate, though with disinclination, a *Mycalesis campina*. After three more small grasshoppers she persistently refused to have anything to do with a second *Mycalesis campina*, but accepted and ate, again with an air of disinclination, a *Neptis agatha*, afterwards refusing persistently once more to touch the *Mycalesis campina*. I then offered a Coprid which I had found rolling a millipede. She eagerly seized it, but directly pressure was applied to its glossy surface the beetle shot away to the other side of the cage. Three or four times the roller obtained an excellent grip, but quite failed to crush the beetle, though she appeared to exert her greatest force, and the end was always the same—the beetle shot out violently and rebounded from the side of the cage. At last the bird lost her temper and taking it from the forceps dashed it to the ground, after that edging away every time I offered it. I then offered the millipede (*Spirostreptus* sp.). She crushed it three or four times with her bill and rejected it; then refused to accept *Neptis agatha* or a *Mycalesis campina*.

[*Neptis agatha* was preferred to *Mycalesis campina*, and at this stage the roller was deterred by *Sceliages adamastor* from continuing her attempts to crush it after about four attempts, hardness and gloss being the qualities that led to this result. A broken-up millipede, probably dead for some time, was rejected at the same stage.]

Exp. 99.—October 23. Had been feeding on grasshoppers. I offered her a wingless *Pyrameis*, the top of whose thorax I had smeared thinly with honey. The roller accepted it readily, but at once flung it away in disgust and wiped her bill vigorously on the perch. She then refused without tasting *Neptis agatha*, but readily ate some working termites, of which insects she is usually not very fond.

The experiment suggested that a new, strong or unexpected taste not in itself unpleasant may cause suspicion in an experienced bird and bring about rejection. It was carried out to test this view.

Exp. 100.—October 24. Readily ate a *Mycalesis campina*, then accepted a Coprid found rolling dung yesterday in the forest, crushed it for some time without however breaking it up greatly, and swallowed it. She did not experience with this beetle the difficulty of the other day. She then tasted and rejected an *Aletis monteironis*, readily ate a *Terias*, and tasted and at once rejected a Lycoid beetle.

I now fed her up on grasshoppers, &c., till she would eat no more, absolutely refusing several favourite species in succession. She then refused a *Mycalesis campina* and tasted and rejected *Neptis agatha*. Thereupon I offered her *Plasiorrhina plana*, a large black Cetoniid beetle crossed by a white bar which occurs now at the bananas. She had the greatest difficulty in dealing with this; it occasionally slipped out of her bill, though less so than the Coprid of the other day; once it succeeded in opening its wings and gave vent to a loud buzz like that of a *Xylocopa* bee. The roller at once dropped it in alarm and on my reoffering it only accepted it after marked hesitation. Three times the insect, held back downwards, clasped the bird's upper mandible with its particularly tenacious feet. This irritated the bird beyond measure; it was only with the greatest difficulty that she managed each time to extricate herself from the Cetoniid's embrace and she at once flung it away with a great show of rage, finally refusing to have anything more to do with it. She then refused without tasting *Neptis agatha*, accepted a speckled Cetoniid, *Diphrontis vethi*, captured to-day in the forest, and obtaining without difficulty a good grip on it, for it was flat in shape and not markedly slippery, she crushed it with her bill, but, making very little impression, battered it well against the perch (the beetle once slipped from her bill and had to be re-offered), crushed it again for some time with her bill, this time with greater success, and swallowed it still very much alive. She then reaccepted though without eagerness the first Cetoniid. It at once shot out of her bill when pressure was applied, and the bird refused persistently and repeatedly with emphatic shakes of the head to have anything more to do with it.

Twenty minutes later I offered it again, when it was distinctly tasted, the bird obtaining a good grip, and rejected. *Neptis agatha* was refused without tasting. Ten minutes later the bird again tasted the Cetoniid, once more obtaining a firm grip and crushing well in, and ended by flinging it away. It was quite evident that it was not liked. She then readily ate *Neptis agatha*, and obstinately refused with many shakes of the head to taste the beetle again.

Half an hour later, no food meantime, I offered a *Belenois mesentina*. The bird, at the far end of a perch, edged up with a certain amount of hesitation, tasted it cautiously, and retired with a shake of the head.

[SUMMARY:—*Terias* preferred to *Aletis*, *N. agatha* to *Plasiorrhina plana*, and *Diphrontis vethi* found easier to manage than the *Plasiorrhina*, which was itself also possessed of some unpleasantness in addition to its very excellent deterrent degrees of hardness, gloss, and clawing. The Coprid was eaten without much breaking at the stage of refusing *Aletis* but eating *Terias*. Somewhat high unpleasantness of *B. mesentina* reaffirmed.]

Exp. 101.—October 28. I fed the bird on grasshoppers till she persistently refused to touch another. She then refused, but on my pressing her tasted and rejected a *Papilio angolanus*, crushed and readily ate a pupa of a Longicorn beetle, *Anthores leuconotus*, refused, then tasted and rejected a dead but supple *Papilio ophidocephalus* without wings, readily ate a *Catacroptera cloantha*, and once more tasted, this time crushing it better, and rejected a *Papilio ophidocephalus*.

[That is to say, *Catacroptera cloantha* and the pupa of *Anthores leuconotus* were preferred to any grasshoppers, to *Papilio ophidocephalus*, or to *P. angolanus*.]

Exp. 102.—*November 3.* Fed on grasshoppers till she repeatedly and persistently refused to eat any more, though several palatable species were offered. She then readily ate two large moths, *Sphingomorpha chlorea*, crushed and rejected a *Papilio lyæus*, and refused without tasting an *Aterica galene* (♂), headless and with half a hindwing attached, the latter perhaps reminding her of *Neptis*. There was in any case no mistaking the fact that she was thoroughly replete. On my continuing to present the insect she took it, and without crushing it threw it away, doing this a second time on my continuing to offer it. I then offered her a *Precis cebrene* with two wings attached. She similarly refused this, then took and threw it away, and, as in the case of the *Aterica*, once more threw it away (this time, however, first actually crushing it) on my continuing to reoffer it. On my reoffering it yet again she accepted it, crushed it with more deliberation, and swallowed it without a sign of dislike, but refused *Papilio lyæus*. She then, though with disinclination, accepted the *Aterica*, crushed it with the same deliberation, as in the case of the *Junonia*, and swallowed it, again with apparent relish. She then persistently and repeatedly refused to touch *Papilio lyæus*. Five minutes later I offered her a ♀ *Arrugia basuta*, a *Precis cebrene* (upperside exposed) and a *Hamanumida dædalus*, but she persistently refused all without tasting, being thoroughly gorged.

[SUMMARY :—

1. *P. cebrene* and *Aterica galene* ♂.
2. *P. lyæus* and grasshoppers.

Sphingomorpha chlorea was preferred to the grasshoppers, and the *Aterica* was eaten up to refusal-point for *Arrugia basuta* ♀, *P. cebrene*, and *H. dædalus*.]

Exp. 103.—*November 11.* I fed the bird on grasshoppers till she finally and repeatedly refused to accept any more. She then accepted *Papilio angolanus* with an air of hesitation, crushed it slightly and at once flung it right away, readily but slowly, being evidently nearly replete, crushed and ate a *Charaxes brutus* and a *Charaxes candiope*, refused without tasting a *Hypolimnias wahlbergi*, which she seemed to view with suspicion, barely crushed it, if at all, and threw it away; then with equal disinclination accepted a *Precis cebrene* and crushed it too and threw it away. Three minutes later she again accepted and this time ate the *Precis cebrene*, but persistently refused to taste the *Hypolimnias wahlbergi*, even on my removing its one wing. She finally took it and repeatedly tossed it into the air, catching it each time as it fell. She then dropped it and refused persistently to accept a *Precis cebrene* or a ♂ *Arrugia basuta*. Five minutes later she refused for a time but afterwards crushed and rejected the *Hypolimnias wahlbergi*, but readily ate a ♀ *Arrugia basuta*.

Ten minutes later she refused *Hypolimnias wahlbergi* without tasting, readily accepted and ate *Catopsilia florella*, once more persistently refused to taste

Hypolimnas wahlbergi, readily ate a ♂ *Arrugia basuta*, then, after refusing it again, accepted, crushed well and rejected the *Hypolimnas wahlbergi*.

Twenty minutes later by dim lantern light she crushed and readily swallowed the *Hypolimnas wahlbergi*, but rejected with every sign of disgust a *Papilio angolanus*, also without wings.

[SUMMARY :—

- (a) 1. *Charaxes brutus* (and *C. candiope*?).
- 2. *P. angolanus* and grasshoppers.
- (b) 1. *Arrugia basuta* ♂ and ♀, and *C. florella*.
- 2. *Hypolimnas wahlbergi* (not worse, probably better, than *P. angolanus*).]

Exp. 104.—November 13. Fed on grasshoppers till she persistently refused to accept another (several favourite spp. were refused), she ate but with disinclination a *Papilio angolanus* and refused to have anything to do with a second. She then accepted eagerly enough, crushed slightly and nearly swallowed a large Saturniid moth without wings, but brought it forward into her bill once more and subjected it to a very prolonged tasting, evidently feeling quite doubtful about it, before finally throwing it away. She then once more refused to taste *Papilio angolanus*, but accepted, crushed well, and swallowed with apparent relish a large Noctuid, *Argadesa materna*, with two wings attached to distinguish it from the Saturniid. She then, evidently quite replete, refused persistently without tasting a *Precis cebrene*, a ♂ *Arrugia basuta*, a *Catopsilia florella*, and a *Charaxes cithæron*.

Fifteen minutes later she refused *Papilio angolanus*, then barely closed her bill on one of its antennæ and withdrew with shakes of the head; refused the Saturniid moth and then, as in the case of the preceding offering, barely closed her bill on it and withdrew with signs of dislike. She readily, however, ate the *Precis cebrene* and the ♂ *Arrugia basuta*, but refused, then crushed well, and rejected the *Catopsilia florella*. It appeared just possible that she had in mind other and distasteful white species and did not allow the evidence of her taste to overcome her suspicions, for she now readily enough accepted and ate another *Arrugia basuta* (♀).

[SUMMARY :—

- 1. *P. cebrene*, *Arrugia basuta* ♀ (and probably ♂), *Argadesa materna* (the latter to refusal-point for *P. cebrene*, *Arrugia basuta*, *C. florella*, and *Ch. cithæron*).

Saturniid. { 2. *P. angolanus*.
3. Grasshoppers.]

Exp. 105.—November 14. Refused, then tasted and rejected an *Aletis monteironis*, persistently refused even to taste *Mylothris yulei*, but readily ate a *Mycalis campina*. She then ate three smallish grasshoppers and refused without tasting, but, changing her mind, accepted and swallowed another *Myc. campina*. She exactly repeated the performance in connection with each of five more *Myc. campina*, offered as before at intervals of three grasshoppers. She then

crushed well and swallowed without sign of dislike yesterday's Saturniid moth and after it another *Mycalesis campina*, and, to my surprise, a *Terias*, having persistently refused to taste a *Mylothris yulei* before the last acceptance.

[Note: "Each *Mycalesis* in this experiment, as also the *Terias*, was at once swallowed down, wings and all, without any attempt at preliminary crushing. The experiment ran very quickly in spite of the refusals, and it seemed to me that the bird was in rather a reckless mood, and, starting very hungry, decided each time to swallow the insect and chance the results, though probably already past the stage at which it would ordinarily have rejected it. Thus, all that can be said with regard to the Saturniid is that it is less unacceptable than *Mylothris yulei* and *Aletis monteironis*, probably hardly *distasteful* at all in view of its treatment yesterday by the roller and on the 2nd by the kingfisher."

It is interesting to let the above note stand, but actually, no doubt, the acceptances of this experiment were excellent and extreme instances of the result of special stimulation by "the preceding offering." However, *Terias* and *M. campina* were preferred to *M. yulei*, and the *Mycalesis* at any rate to *Aletis monteironis*.]

Exp. 106.—November 16. Hungry; tasted and at once rejected an ant (*Myrmicaria eumenoides*, Gerst.), readily ate a *Papilio angolanus*, tasted and rejected another ant (*Dorylus gerstaeckeri*, Emery), ate with apparent relish a *Terias*, tasted and flung away with marked disgust an *Osprynchotus flavipes* ♀. I then fed her upon grasshoppers till she persistently refused several favourite species in succession, after which she tasted and rejected (after at first refusing each) *Papilio angolanus* and *Leuceronia thalassina* ♀, but readily ate *Catacroptera cloantha*, ♂ *Arrugia basuta*, and two spp. of moths, *Sphingomorpha chlorea* and another, two of each, refusing the rest as also *Precis cebrene*, undoubtedly through sheer repletion.

[SUMMARY :—

1. *Cat. cloantha* (and perhaps, but not certainly, *A. basuta* ♂ and the two moths).
 2. *P. angolanus*, *Terias*, grasshoppers.
 3. *Myrmicaria eumenoides* and *Dorylus gerstaeckeri*, also, on manner, *Osprynchotus flavipes* ♀.]
- L. thalassina* ♀.

Exp. 107.—November 25. Readily ate a *Mycalesis campina*, three small grasshoppers, another *Myc. campina*, three more grasshoppers and a third *Myc. campina*, three more grasshoppers and a fourth *Myc. campina*. She then, after yet another three grasshoppers, refused persistently to touch a *Myc. campina*, a *Neptis agatha*, a *Papilio angolanus*, or a *Herpænia eriphia*.

Ten minutes later she refused for a time but finally accepted and ate a *Myc. campina*, and, more readily, a *Papilio angolanus*; refused, then tasted and rejected a second *Myc. campina*, but readily ate, after tasting it well, the *Herpænia eriphia*; refused, then tasted very slightly and once more refused a *Myc. campina*, tasted and rejected a *Phymateus viridipes*, refused persistently to touch a portion of its abdomen which I broke off and offered in case the whole insect had been too

large or too much trouble to eat in the then state of her appetite, edging away from it when I continued to hold it to her; refused for a time a *Myc. campina*, then tasted it slightly and withdrew from it, and finally knocked it out of my forceps irritably with a sidelong blow of her bill. She readily, however, ate a *Neptis agatha*, then once more refused the *Myc. campina*.

[SUMMARY:—*H. eriphia*, *N. agatha*, and, on manner, *P. angolanus* were preferred to *M. campina*, and *N. agatha* to *Phymateus viridipes*.]

Exp. 108.—November 26. Noticing that the two fragments of yesterday's *Phymateus* (the thorax was still alive) had almost completely lost their characteristic smell (it was still just noticeable on opening the wings at the point where they joined the thorax), I decided to once more offer it to the roller. I therefore fed her till she refused to eat any more grasshoppers, and refused, then doubtfully tasted and rejected *Papilio angolanus*. She then accepted the *Phymateus* abdomen and subjected it to a very prolonged tasting, making once or twice as though to swallow it before at last rejecting it. I then reoffered it twice and it was each time once more accepted, crushed, and dropped. On the third occasion it was refused without tasting.

Ten minutes later she again refused, but after some persuasion tasted slightly and rejected *Papilio angolanus*, twice tasted and doubtfully rejected a small portion of the *Phymateus* abdomen, afterwards refusing it without further tasting, and twice tasted and dropped its thorax, afterwards refusing it too without tasting. She then accepted an unidentified beetle, pressed it once or twice, but made no real attempt to crush it, and finally dropped it, obviously because too replete to go to the trouble of crushing it. On my reoffering it, she treated it again in the same way. She then tasted slightly and rejected *Papilio angolanus*, crushed and readily ate *Precis artaxia*, refused through sheer repletion, then accepted and ate a *Precis madagascariensis*; refused, then ate a ♀ *Arrugia basuta*; refused, then ate two *Precis artaxia* and rejected with disgust the Meloid beetle, *Lytta designata*, exuding from its thorax a small quantity of yellow juice.

Ten minutes later she readily ate after crushing it the small Cetoniid, *Leucocelis parallelocollis*, experiencing no difficulty from its hardness or polish.

[SUMMARY:—Note: "The long and repeated trials given by the roller to-day to the *Phymateus* when practically replete contrasted strongly with its prompt dismissal of the insect yesterday when considerably hungrier, and seemed to show that the unpleasant taste and odour are chiefly confined to its frothy exudation and disappear with its disappearance."

P. ataxia (and probably *P. madagascariensis*, *Arrugia basuta* ♀, and *Leucocelis parallelocollis*) was preferred apparently to *P. angolanus*, the unidentified beetle (which the roller at that stage of appetite would not trouble to crush), *Phymateus viridipes*, and even favourite species of grasshoppers.]

Exp. 109.—November 27. Tasted well and rejected a *Zonocerus elegans* and refused persistently without tasting a wingless *Acraea esebria*, retreating before it when I continued to offer it. It was interesting that after this lapse of time she should continue to remember clearly the Acraeine body and to associate it with a

high degree of unpleasantness, for she was unmistakably hungry and would I feel sure have eaten a *Terias*, judging from the avidity with which she now accepted and swallowed down a *Mycalesis campina*. It is interesting in this connection to note that on my commencing the above experiment the roller was hopping about on the ground searching for food and picking up an occasional working termite. Nevertheless, she failed to see a solitary larval grasshopper which was lying motionless on the floor. She usually eats it right up to the end when offered by the forceps, yet now she passed over it two or three times without seeing it. I have noticed this difficulty in distinguishing motionless objects frequently before on the part, not only of the roller, but of my various other insectivorous birds, and one sees exactly the same thing in buck and other wild mammals. Had the grasshopper moved it would probably have at once been snapped up. I now fed the bird by hand and somewhat later in the day offered her a *Myc. campina* which she readily ate. She then accepted readily a *Pachnoda impressa*, but absolutely failed to eat it, as the beetle slipped with a snap from her bill each time she applied any pressure. She then ate readily three smallish grasshoppers, including the one that had been lying in the cage all day; refused, then tasted slightly and rejected a *Myc. campina*. I then reoffered the Cetoniid, but she again failed to crush it owing to its extreme slipperiness and toughness. She commenced by refusing it without tasting, but on my continuing to offer it, she made quite a number of attempts to crush it, sometimes succeeding in holding it in her bill while she struck it several times against the perch, but it always slipped out in the end and the bird finally refused to have anything more to do with it, edging away whenever it was offered. She then ate readily a *Eurytela hiarbas*, but refused and on persuasion tasted slightly and rejected a *Myc. campina*.

[*M. campina* preferred to *Z. elegans* and *A. esebria* (or whatever this was taken for); grasshoppers and *E. hiarbas* eaten after the bird had failed to eat *Pachnoda*. The defence afforded the latter by gloss and toughness was well illustrated; also the roller's memory and capacity for recognizing even a wingless Acraëne body by the incident of the *A. esebria*.]

Exp. 110.—November 28. Hungry; she at first refused without tasting a *Pachnoda impressa*, evidently remembering her experience of yesterday, but on my persisting in offering it, accepted it several times in succession. It each time, however, slipped out of its bill and the bird only twice or thrice arrived at the stage of banging it against the perch—for she seemed to realize that this was the correct procedure here, crushing with the bill being out of the question. She finally refused to have anything more to do with it.

After an interval I offered her another Cetoniid, *Rhabdotis aulica*, a somewhat large metallic-green species. She at once accepted it, but only to go through once more the tantalizing performance which she had experienced in connection with the *Pachnoda*, with the result that the *Rhabdotis* too was soon given up as a bad job, the bird showing irritation whenever I brought it near to her. She then

tasted and rejected a *Lytta designata*, but eagerly accepted and ate a *Eurytela hiarbas* and a *Mycalesis campina*.

[A good illustration of the value of the defences of gloss and toughness. *L. designata* placed below *E. hiarbas* and perhaps *M. campina*.]

Exp. 111.—December 1. Hungry; early morning; no food yet. Crushed and readily ate the Carabid beetle, *Polyhirma ænigma*, in spite of its strong, sour, vinegary smell; crushed and rejected the Chrysomelid, *Hemiphracta abyssinica*, readily ate a second Carabid, *Platynus* sp., refused, then tasted with hesitation and rejected a larva of *Epilachna hirta*, and refused to touch *E. hirta*, imago. After a great deal of persuasion, however, she tasted it slightly and rejected it.

[That is, the *Polyhirma* and the *Platynus* were preferred to the *Hemiphracta*, and quite likely also to the larva of *Epilachna hirta*, and to *E. hirta*, imago, and all these rejected insects were probably very much disliked, as the roller was very hungry.]

Exp. 112.—December 2. Tasted and at once rejected a Chrysomelid beetle, *Exosoma bimaculata*, and an *Aletis monteironis*, but ate with the greatest readiness a *Mycalesis campina*.

After a further interval without food I gave her a large black highly-polished Cetoniid, *Diplognatha gagates*. Though very hungry she completely failed to eat it. Time after time she accepted and attempted to crush it, or even got so far as to commence to batter it, but the beetle every time slipped from between her mandibles and shot across to the other side of the cage to the bird's intense annoyance. She then ate readily not only a *Myc. campina* but an *Aletis monteironis*, offered as before with all wings attached. She then once more went through the same performance with the Cetoniid and completely failed to eat it.

I then fed her up on grasshoppers till she persistently refused to eat another, although several favourite species were offered. I then thrust through the bars the *Diplognatha gagates* and used my utmost powers of persuasion to obtain its acceptance. The roller would, however, have nothing whatever to do with it, evidently not realizing—for the wings, too, are black—that it had been rendered easier to crush, but she readily ate a *Catacroptera cloantha* with all its wings attached, afterwards once more refusing to touch the Cetoniid.

[SUMMARY:—

	1. <i>Myc. campina</i> .	} <i>Cat. cloantha</i> .
<i>Exosoma</i>	2. <i>Aletis monteironis</i> .	
<i>bimaculata</i> .	3. <i>Diplognatha gagates</i> (complete failure)].	

Exp. 113.—December 3. After a little hesitation tasted well and rejected an *Acraea johnstoni* with pale buff hindwing patch, and refused most persistently even to taste the larva of a Coccinellid, owing no doubt to its general likeness in form though not altogether in colour to that of *Epilachna hirta* with which she is already acquainted.

I then fed her on grasshoppers till she refused absolutely to touch another. Five minutes later she ate two more, both very small, and refused most persistently to accept another though I offered several species, but accepted, crushed, and very readily ate *Aterica galene* ♀ (one hindwing attached) and *Hypolimnias wahlbergi* ♀. She then refused *Papilio angolanus* without tasting, but on my continuing to press it on her accepted, crushed, and at once rejected it. This was repeated twice again, the roller being attracted back to it each time by the butterfly's violent fluttering, but after that she refused persistently to taste it again, moving away whenever I brought it near.

Ten minutes later she for a minute or two refused to taste *Pseudacraea lucretia*, a black and white ♀ with all wings attached, scrutinizing it closely and suspiciously sometimes, but each time withdrawing without actually trying it. At last, however, she accepted it, crushed it very thoroughly with a doubtful air and practically swallowed it (in good position, head first and wings well back), but at once brought it forward into the bill again and subjected it to a further tasting before finally eating it. She then refused but on my continuing to hold it to her crushed and rejected *Papilio angolanus* and refused a small grasshopper, but after a great deal of persuasion ate the latter and two more, both very small, besides persistently refusing to touch another, though as usual I offered several favourite species. She then refused for a time but eventually tasted slightly and dropped a moth (*Cænina*?), similarly refused but finally ate a ♀ *Arrugia basuta*, and most obstinately refused to touch either a second ♀ *Arrugia basuta* or a *Precis cebre*ne, being evidently quite replete.

Ten minutes later she persistently refused the *Cænina* moth, readily ate an *Anomala ustulatipes* and a ♀ *Arrugia basuta*, refused for a few seconds but then accepted and ate a second, readily ate a ♂ *Arrugia basuta* and a *Precis cebre*ne, refused most obstinately to touch a *Papilio angolanus*, and refused for a time but finally, changing her mind, ate an *Anomala ustulatipes*. Ten minutes later she crushed rather doubtfully and ate a *Cænina* moth and a *Precis cebre*ne, but refused a ♀ *A. basuta* and a second *Precis cebre*ne.

[SUMMARY:—(1) Note: "As I had no butterflies of the second class (*Papilio lyæus* or *demodocus*) to offer, it is impossible to say that one of these would not have been eaten at the moment at which I offered *Aterica galene* and *Euralia wahlbergi*. The contrast between the relish with which these two butterflies were eaten and the promptness with which *Papilio angolanus* was each time rejected would, however, indicate that neither were *less* liked than *Papilio lyæus* would have been, for the gap between the latter butterfly and *Papilio angolanus* is not at present great."

(2) Probable order:—

1. *Aterica galene*, ♀ *Anomala ustulatipes*, and perhaps *Arrugia basuta*, *Precis cebre*ne, and *Hyp. wahlbergi*.
2. The better grasshoppers, the moth, and *P. angolanus*, the moth being finally eaten with doubt up to *cebre*ne refusal-point.

3. The close inspection and very wary trial of the *Pseudacraea* was of rather special interest.]

Exp. 114.—December 4. Hungry; tasted and rejected *Mylothris yulei* ♂, *Aletis monteironis*, *Exosoma bimaculata*, and an ant (*Platythyrea cribrinodis*), but ate with the greatest eagerness *Mycalesis campina*.

After an interval, the bird receiving no food meantime, she readily ate after crushing it the *Mylothris yulei* (a ♂ with smell strongly developed), wings and all, crushed and rejected *Exosoma bimaculata* and *Platythyrea cribrinodis*, but ate, though with dislike and after an unusually prolonged crushing and battering, an adult ♀ locust, *Zonocerus elegans*.

[Probable order :—

Zonocerus { 1. *M. campina*.
 { 2. *M. yulei*.

3. *Exosoma bimaculata* and *Platythyrea cribrinodis*.]

Exp. 115.—December 5. Tasted and at once rejected with disgust a beetle (*Lycus*); refused, then crushed and rejected a *Mylothris yulei* ♂, but without special signs of disgust; refused for a time, then tasted and rejected with disgust a larva of a Coccinellid, but eagerly ate a *Mycalesis campina* and, after distinctly tasting it, a *Tarucus plinius*. She then ate fifteen small grasshoppers in quick succession and, after them, readily, a second *Tarucus plinius* and another *Mycalesis campina*, also a small white moth. After seven more small grasshoppers she again readily ate a *Myc. campina*, and after five more refused for some seconds, then tasted and rejected an *Azanus moriqua*, but on my reoffering it again tasted and this time swallowed it. She then accepted and ate a *Mycalesis campina*, but treated a *Tarucus plinius* exactly as she had done the *Azanus*, eating it similarly in the end.

After three more grasshoppers she refused, then tasted and rejected both *Azanus moriqua* and *Tarucus plinius*, and afterwards refused obstinately to have anything more to do with them; refused a *Mycalesis campina*, then leant forward and nearly closed her bill on it, but withdrew without removing it from the forceps. Five minutes later she refused the *Myc. campina* with shakes of the head and clappings of the bill, tasted hesitatingly and rejected in turn *Lampides baetica* and *Tarucus plinius*, and five minutes later persistently refused to taste either again.

Fifteen minutes later she refused obstinately to taste a *Nacaduba sichela*, though she once leant forward doubtfully and nearly did so; accepted doubtfully, but then ate with apparent relish a *Henotesia perspicua*, persistently refused to even taste a *Terias*, and refused for some seconds, then tasted slightly and hesitatingly and withdrew without actually accepting the *Nacaduba sichela*. She then ate in quick succession eight more grasshoppers before refusing to eat more—as usual I now offered several palatable species without succeeding in tempting her appetite,—persistently refused to touch *Catachrysops dolorosa* or a *Papilio angolanus*, but very readily accepted and ate an *Arrugia basuta* ♂.

The butterflies in the above experiment had all wings attached. The Lycænids were quite evidently disliked.

[Probable order:—

	1. <i>Arrugia basuta</i> .	} <i>Henotesia perspicua</i> .
	2. Grasshoppers.	
C. dolorosa (if recognized), P. angolanus.	3. <i>M. campina</i> .	} <i>L. bætica</i> & <i>N. sichela</i> , probably not appreci- ably if at all above <i>M.</i> <i>campina</i> .]
	4. <i>Azanus moriqua</i> , <i>Tarucus plinius</i> .	
	5. <i>M. yulei</i> (on manner).	
	6. <i>Lycus</i> , Coccinellid.	

Exp. 116.—December 6. Fed on grasshoppers till she would eat no more; readily ate two winged termites, a Catocaline moth (*Ophiusa lienardi*) and a Rutelid beetle (*Adoretus* sp.), as also another termite; crushed and rejected an orange-banded Longicorn, *Cymatura bifasciata*, but readily ate yet another termite.

[Probable order:—

1. Termite, *Ophiusa lienardi*, *Adoretus* sp.
2. Grasshoppers, *Cymatura bifasciata*. The latter, however, was definitely tested only against the termite.]

Exp. 117.—December 7. Distinctly hungry. Crushed and at once rejected the Arctiid moth, *Diacrisia maculosa*, exuding juice from before thorax, as also an unidentified Coccinellid, refused persistently to taste *Epilachna hirta*, but eagerly accepted and ate a *Mycalesis campina* and a *Terias*, refused, then hesitatingly tasted, and withdrew without accepting an *Acræa caldarena*, and once more, this time after a more thorough tasting, rejected the *Diacrisia*.

I then fed her on various Orthoptera till she would absolutely eat no more. After this she refused for a time to accept *Papilio angolanus*, but finally just tasted a leg and withdrew with a shake of the head, then accepted with a certain amount of hesitation, due perhaps to its brilliant coloration, the front half of a full-grown larva of *Acherontia atropos* which I had that moment cut in two, but dropped it. This was probably, however, either the result of accident or of the surprise due to the sudden rush of its copious internal juices into the bird's bill, for on my reoffering it, it was readily accepted, crushed and battered against the perch and swallowed. The bird now refused without tasting an *Arrugia basuta* ♀, a *Catacroptera cloantha*, a *Catopsilia florella*, and a *Precis cebrene*, being to all appearance replete. She kept wiping her bill, however, at intervals and shaking her head, which I took to be possibly a sign that she regretted having eaten the larva (though it may have been simply a matter of its juices), so fifteen minutes later I offered the other half. The bird looked at it and sidled up towards it from the other end of the perch, but did not at once accept it, leaning forward on arrival but then drawing back once more with a shake of the head. A few seconds later she tasted it half-heartedly and again drew back without having accepted it. She then refused, but changing her mind accepted, crushed and ate a *Catacroptera cloantha*, but refused persistently to taste a *Precis cebrene* or a *Catopsilia florella*, being evidently too replete for them.

The "death's-head" larva evidently continued to tempt her nevertheless, for on my now at once reoffering it she once more leant forward and closed her bill on it,

but did not take it from the forceps. She then again persistently refused to accept a *Precis cebrene* and crushed slightly and tossed aside an *Adoretus*.

Somewhat later by lamplight the roller very persistently refused with shakes of the head to have anything to do with *Papilio angolanus*, readily accepted and ate an *Arrugia basuta* ♂, accepted equally readily, crushed and battered well and swallowed the remaining half of the death's-head larva, crushed and threw aside an *Adoretus*, and refused without tasting a ♀ *Arrugia basuta*.

[SUMMARY:—(1)

<i>Arrugia basuta</i> .	{	1. <i>C. cloantha</i> , slightly above
		2. <i>Acherontia</i> larva, which was eaten to refusal-point for <i>Arrugia</i> , <i>C. florella</i> , <i>P. cebrene</i> .
		3. <i>P. angolanus</i> .

Adoretus (prob.).

M. campina and probably the *Terias* were preferred to *Diacrisia maculosa*, which, on the manner of its last refusal, was perhaps preferred to *A. caldarena* and the two Coccinellids.

(2) Note: "The refusals of *Papilio angolanus* were very decided and final, and there can be therefore no escape from the conclusion that the larva was no more unacceptable to the roller than is *Papilio lyæus*, possibly less so. I confess that I was surprised in view of its coloration.

The *Diacrisia* is quite likely on a level with *Nyctemera*—it is certainly markedly less unpleasant than *Acræa caldarena*."]]

Exp. 118.—December 9. Very hungry, tasted and rejected *Acræa igola* and *Acræa johnstoni*, refused without tasting an adult *Zonocerus elegans*, and tasted and rejected the same locust in the larval stage.

Exp. 119.—December 10. Ate a large number of grasshoppers, but at last refused persistently to touch any more, and refused with equal obstinacy, without tasting it, a *Papilio demodocus* with wings attached. She quite readily however accepted, barely crushed, and at once swallowed an Acræoid Lycænid, *Catochrysops peculiaris*. She then definitely tasted and rejected the *Papilio demodocus*, and, on my removing and offering the abdomen alone, tasted it too and rejected it. She then examined a *Hypolimnas wahlbergi* with one wing attached with an air of doubt and then withdrew and for a long time would not taste it. Finally she did so, slightly and with hesitation, and dropped it, then with the greatest readiness accepted, crushed and ate *Precis tugela* with one forewing attached. She then once more refused, but, changing her mind, tasted the *Hypolimnas wahlbergi* and rejected it, readily accepted and ate *Hamanumida dædalus*, refused again, then tasted, this time much more thoroughly, and rejected the *Hypolimnas wahlbergi* (she crushed it repeatedly with an air of uncertainty, as though undecided whether to eat it or not), but readily ate a *Catacroptera cloantha*, again refused *H. wahlbergi* for a second, then leaning forward took an antenna in her bill and withdrew with a slight shake of the head, readily ate a dead but supple *Catochrysops parsimon*, refused obstinately to taste *Hypolimnas wahlbergi*, readily accepted, crushed and ate a *Precis artaxia*, refused,

then tasted well *H. wahlbergi*, being again quite obviously uncertain whether to eat it or not, but ended by once more rejecting it, though she readily ate a *Charaxes achæmenes* and a ♂ *Arrugia basuta*.

Ten minutes later she refused the *Euralia wahlbergi* for a second or two, then crushed and rejected it, and crushed well and rejected the Longicorn beetle, *Cymatura bifasciata*. She then suddenly noticed a *Mutilla* that was climbing up the side of the cage and leaning over seized it, the ant making no attempt to escape, crushed it—its strong smell reached my nostrils two or three feet away as she did so,—and threw it away.

Fifteen minutes later she crushed and ate *Papilio demodocus*, tasted and rejected the *Cymatura*, refused, then merely took and threw aside *Hypolimnias wahlbergi*.

Five minutes later she tasted and hesitatingly dropped *H. wahlbergi*, refused, then tasted perfunctorily and rejected a *Mycalesis campina*, crushed and swallowed a *Papilio angolanus*, the *H. wahlbergi*, and a *Catachrysops dolorosa*, refused to touch a *Mycalesis campina*, refused, then tasted unwillingly and rejected a *Papilio angolanus*, subsequently refusing obstinately to taste it again, crushed well and doubtfully and finally ate the *Cymatura*, and once more persistently refused to have anything to do with *Papilio angolanus*.

[SUMMARY :—

(1) If we take manner freely into account we have the order :—

1. *C. peculiaris*, *C. parsimon*, *A. basuta* ♂, *P. tugela*, *P. artaxia*,
H. daedalus, *C. cloantha*, *C. achæmenes*.
2. *P. demodocus*. *Cymatura bifasciata* not above it.
3. *P. angolanus*.
4. *H. wahlbergi* (might have gone higher, but for special suspicions).
5. *M. campina*, *Mutilla* sp.

(2) Against the above suggestions concerning *H. wahlbergi* we have the following note, made at the time of the experiment :—

“The bird had thus accepted and eaten the *Hypolimnias wahlbergi* exactly at the *Papilio angolanus* point—at the moment when she could just bring herself to eat a single *Papilio angolanus*,—but not a second. That is to say, the Nymphaline was placed on a level with *Papilio angolanus*. I doubt whether this result was due to any appreciable extent to the latter's resemblance to *Amauris dominicanus* (it had a hindwing attached); it seems more likely (and accords with the fact that the roller's tastings of it were characterized by hesitation) that though thoroughly palatable this butterfly is slightly unwholesome and that the roller retained a memory of its effects on itself on previous occasions.”

I also recorded that I regarded *C. peculiaris* as having been hardly sufficiently tasted for a sure result.

Exp. 120.—December 12. I fed the bird on grasshoppers till she began to accept and eat them with distinct disinclination. She then accepted a brightly coloured bug, *Cryptacrus comes*, crushed it well, shaking her head greatly all the time, though with long sweeps, as though to get her nostrils clear of the strong

bitter-almond stench, and swallowed it. Her behaviour reminded me of that shown previously in connection with a Coreid bug, when I compared it to a person swallowing a rather *too* strong liqueur. She then refused two dull-coloured and usually highly acceptable grasshoppers.

Ten minutes later she ate six or seven small grasshoppers before refusing to eat any more, and then would also have nothing to do with a second bug of the same species.

[This bug was probably placed quite as high as, e. g., *P. angolanus*.]

Exp. 121.—*December 13.* I fed the bird on grasshoppers till she refused absolutely to eat any more. She then persistently refused *Papilio angolanus* without tasting and with shakes of the head, tasted and rejected a ♀ *Papilio echerioides*, dead but supple, again refused with shakes of the head the *Papilio angolanus*, but readily accepted and ate, the second slowly, two moths, both *Ophiusa lienardi*. She then crushed and held for some seconds the large common brown Asilid, *Alcimus rubiginosus*, simply however through comparative repletion, for she then swallowed it without sign of dislike, as also the moths *Spirama capensis* (Catocaline), *Ægocera fervida* (Agaristid), *Cylogramma latona* and *Nyctipao macrops* (both Catocalinæ). The *Ægocera* received a longer crushing than the others, and was practically swallowed once and brought up again before being finally swallowed. That it was eaten at all a little surprised me, for it possesses a strong smell of its own which I have always taken to be the outward and tangible sign of some inward and unpleasant properties.

The huge *Nyctipao*, which I offered without wings, on the first—careless—acceptance succeeded, in struggling to escape, in driving its very sharp spines into the bird's lore and was at once hastily dropped. On my reoffering it it was accepted quite readily, but the bird this time took the precaution of seizing it firmly right across the thorax and crushing it at once. She was now utterly replete and refused persistently even to taste *Precis cebrene*, *Catopsilia florella*, and *Ophiusa lienardi*.

Twenty minutes later she accepted with hesitation, crushed and rejected the foreleg of a rat (*Mus decumanus*), refused without tasting *Papilio angolanus* and *Papilio echerioides* ♀, but readily ate *Precis cebrene*.

[SUMMARY :—

1. *Ophiusa lienardi* (and, in so far as not merely the result of stimulation, *Alcimus rubiginosus*, *Spirama capensis*, *Cylogramma latona*, and *N. macrops*) to *cebrene*, etc., refusal-point.
- P. echerioides* ♀, leg of *Mus decumanus*, and perhaps in view of its first escape through an effective use of its spines, *Nyctipao macrops*.
2. *Ægocera fervida* (on manner: eaten probably as a result of stimulation).
 3. *P. angolanus*, grasshoppers.]

Exp. 122.—*December 14.* Crushed and readily ate a *Cryptacrus comes*, shaking her head as before, apparently to avoid the smell, and after swallowing it remained with her bill wide open as though to let it escape. Ten minutes later she tasted

and at once flung right away an *Acrea asema*, but readily ate a *Mycalesis campina* and a second bug, and, ten minutes later again, yet another bug—once more with no real sign of dislike. She then looked puzzled over a piece of raw “Zwidata” (*Plectranthus tuberosus*), a native vegetable that is not unlike a Jerusalem artichoke, but accepted, tasted it well, and readily swallowed it.

Later, happening to catch an ichneumon in my hand—*Osprynchotus flavipes* ♂—I offered it to the roller. She tasted and at once rejected it, the ichneumon flying off unharmed, but she crushed and readily ate a *Cryptacrus comes*.

[*M. campina* and *Cryptacrus comes* would appear to have been preferred to *A. asema* and *O. flavipes*. The eating of the bit of *Plectranthus* root was interesting in connection with the question of instinctive recognition of food.]

Exp. 123.—Later experiment. Ate several small grasshoppers, a *Cryptacrus comes*, a *Mycalesis campina*, five more small grasshoppers, a *Mycalesis campina*, a *Cryptacrus comes*, two more small grasshoppers, and again a *Myc. campina* and a *Cryptacrus comes*, three more small grasshoppers, and again a bug, but refused, then changed her mind, and ate a *Mycalesis campina*, then one large grasshopper, after which she refused to eat any more grasshoppers though I offered several, but again readily ate a *Mycalesis campina* and another bug, as also after great crushing and battering a large Saturniid, *Gynanisa ethra*. She then once more refused to eat grasshoppers, but readily ate a *Sphingomorpha chlorea*, refused to have anything to do with a *Myc. campina*, but ate after much crushing—indicative probably of hesitation or disinclination—another large *Cryptacrus comes* (white form) and again refused to taste a *Myc. campina*. She nevertheless accepted and ate a dead *Papilio angolanus*, but once more refused grasshoppers and this time another of the bugs.

[Order :—

Red *Cryptacrus comes*,
Sphingomorphachlorea,
Gynanisa ethra.
 { 1. *P. angolanus*, *Cryptacrus comes* (white form).
 { 2. *M. campina*.
 { 3. Grasshoppers.]

Exp. 124.—December 18. Hungry. Tasted and at once rejected a Phytophagous beetle.

Exp. 125.—December 20. Hungry; refused obstinately to taste a Phytophagous beetle, crushed very thoroughly, obviously half tempted to swallow it, then rejected a Meloid, *Epicauta thoracica*, readily ate a *Myc. campina*, tasted and at once flung away a moth, *Olapa nuda*, tasting it more hesitatingly and again flinging it away on my reoffering it, and once more subjected an *Epicauta* to the same prolonged tasting as before, before finally rejecting it. These Meloids had only just been captured close by, so would presumably still retain their objectionable qualities in full strength. They seemed to be far less unacceptable (whatever their after-effects may be) than the Lymantriid moth.

[Order :—1. *M. campina*. 2. *Epicauta thoracica*. 3. Phytophagous beetle and *Olapa nuda*.]

Exp. 126.—*December 21.* I fed the roller on grasshoppers till she absolutely refused to touch another. She then tasted and rejected *Papilio angolanus*, crushed very thoroughly indeed and ended by rejecting a large ♀ *Gyanisa ethra* (though alive 18 hours before, it was now dead and even, I thought, beginning to smell very slightly), refusing to taste it again on its being reoffered, but crushed and ate very readily a large conspicuous Asilid with a comparatively slow flight, *Microstylum validum*.

[*M. validum* preferred to *Gyanisa ethra* ♀, *P. angolanus*, and grasshoppers.]

Exp. 127.—*December 24.* Refused obstinately to taste a *Terias*, readily accepted and ate a *Myc. campina*, once more refused the *Terias*, and went on to eat no less than eighteen *Myc. campina*, the last few with increasing disinclination. The nineteenth was obstinately refused, but four *Papilio angolanus* were readily eaten, the fifth refused without tasting; a *Myc. campina* refused, then tasted and rejected, and another *Papilio angolanus* taken listlessly and tossed aside. The bird then crushed very thoroughly and ate without apparent dislike a large ♂ *Gyanisa ethra*, refused a *Precis cebrene*, took listlessly, crushed and held, but finally tossed away a *Catacroptera cloantha*, threw away a usually much-liked grasshopper, refused *Catopsilia florella* without tasting, as also a grasshopper of another favourite species, then leant forward as though inclined to accept the mate of the previous Saturniid, a large gravid ♀, but I withdrew it, wishing to reserve it for breeding.

[*Order* :—

- | | |
|----------------------------|--|
| 1. <i>Gyanisa ethra</i> ♂. | } <i>Gyanisa ethra</i> ♀ probably slightly preferred to <i>P. cebrene</i> , <i>C. cloantha</i> , <i>C. florella</i> , and the grasshopper. |
| 2. <i>P. angolanus</i> . | |
| 3. <i>M. campina</i> . | |
| 4. <i>Terias</i> .] | |

Exp. 128.—*December 27.* Tasted and rejected a *Terias*, then refused it without tasting, but readily ate in succession no less than thirty-one *Papilio angolanus*, each with one hindwing attached, the last five or six with increasing and, in the end, marked disinclination. The thirty-second was just taken and tossed away and then refused persistently without tasting. The roller then twice crushed well and finally rejected *Papilio demodocus*, refused *Terias* without tasting (the first *Terias* had been reoffered in amongst the first few *angolanus* and was at once swallowed, whether inadvertently or otherwise it was impossible to say), readily ate, wings and all, a *Precis cebrene* and a *Catacroptera cloantha*; refused even to taste *Catopsilia florella*, readily ate another *Precis cebrene*, persistently refused to taste *Papilio angolanus*, refused, then tasted and rejected *Papilio demodocus*, readily ate two brown Hepaliid moths (*Gorgopis*) and the *Catopsilia florella*, tasted again and rejected *Papilio demodocus*, readily ate a ♂ *Arrugia basuta* and a *Precis ceryne* ♂ f., and battered and broke into three a large ♀ Saturniid with one wing, gravid (*Gyanisa ethra*, Westw.), the pieces falling to the ground. I reoffered the thorax, which was well crushed and readily swallowed. The bird then refused to have anything to do either with the whole abdomen after crushing it carefully or

with a very small piece of it, but readily ate a *P. cebrene* and again refused without tasting the small piece of abdomen. She then refused for a second, but changing her mind accepted, though with marked disinclination, a common grasshopper that she usually accepts amongst the last, crushed it and threw it away, and refused even to taste several others of different species which I now offered her, yet she very readily ate a *P. cebrene*.

More than half an hour later she readily ate a *P. angolanus* and the *Gyanisa* abdomen full of eggs, but then refused to taste a second *P. angolanus* or the *P. demodocus*.

[*Apparent order*:—

- A. basuta* ♂, and, if not merely through stimulation, *P. ceryne* { 1. *P. cebrene*, brown Hepialid (and *C. cloantha*?).
 2. *C. florella* (if not eaten through stimulation).
 ♂ f., and *Gyanisa ethra* (thorax).
 3. *P. demodocus*.
 4. *P. angolanus*.
 5. *Terias*.

The abdomen at any rate of the *Gyanisa* was placed *below* *P. cebrene*.]

Exp. 129.—December 28. Ate very readily indeed several smallish pieces of the whitish meat of a leopard and refused the last, but readily ate a *P. angolanus* and a *Cymatura bifasciata*. She then refused without tasting a portion of a frog with skin attached.

Later I noticed that she had brought up the meat quite undigested in the form of two large pellets, also the *Cymatura*. The beetle was lying by itself untainted by the meat and may of course have been brought up on its own merits. I could find no trace of the *P. angolanus*. If brought up it may have been picked out and swallowed again (*cf.* observation on *Bucorax cafer*).

Several hours after the above experiment I fed the bird up on grasshoppers until she obstinately refused to eat any more, though several favourite species were offered. She then accepted, crushed and ate a *P. angolanus*, wings and all, with a certain amount of disinclination and persistently refused the next without tasting. Yesterday's *P. demodocus* was dead and the thorax slightly dry, abdomen quite damp and supple. I therefore removed the latter and holding the butterfly's hindwing against it offered it, but the bird at first refused it, then leant forward with disinclination, took and dropped it, crushed and at once threw away a *Cymatura bifasciata*, crushed thoroughly and swallowed a *Polyhirma enigma*, crushed well and rejected *Bostrychoplites cornutus*. She was now shaking her head and clapping her bill, possibly, I thought, in regret for having eaten the Carabid (which was smelling appreciably, though not its strongest, when swallowed). I therefore waited until she had once more recovered her usual calm demeanour—a matter of a few minutes—and offered a Lycoid Lygaeid bug.

This was tasted and at once flung away as were also a red millipede (*Spirolobus* sp.) and once more the Bostrychid. A water-bug, *Laccotrephes ater*, L., was then accepted with an air of puzzlement, turned in all directions, and crushed in every conceivable position. Its leathery hide—for that is the only term to describe it—

at once resumed its former shape each time the pressure was relaxed, the bug remaining absolutely motionless with walking-legs all stretched stiffly back under the protection of the abdomen, and claspers stretched stiffly forward but ready to suddenly clasp at whatever came within reach. By thus unexpectedly grasping the wires of the cage the bug was several times wrenched right out of the roller's bill and the latter, heartily annoyed, apparently, by this leathery object that kept catching in everything, at last flung it away in a rage and refused obstinately to take it again. She then seized a smallish Coprid with hard rounded glossy elytra, *Copris orion* ♀, but the beetle at once slipped out of her grasp. She refused to accept it a second time or an *Amiantus globulipennis*, crushed well and threw right away the Lycoid bug, accepted a dark green bug (*Cryptacrus comes* var. *apicalis*, Dist.), which slipped out of her grip the first time (it is harder than *Cryptacrus comes*), but was easily enough crushed on being reoffered and eaten with apparent relish in spite of its strong smell, which it was obvious was noted by the bird. She then went on once more to crush and reject the Bostrychid and to refuse without tasting the *Cymatura* and the water-bug, the Coprid, a *P. angolanus*, and the *P. demodocus*, but to accept and eat most readily a *P. cebrene*.

[Order:—

1. *Polyhirma enigma* (regretted?), *Cryptacrus comes* var. *apicalis*, *Precis cebrene*.

Bostrichoplites cornutus,
Lycoid bug, Red
Millipede, *Laccotrephes*
ater, *Copris orion* ♀ and
probably *Amiantus*
globulipennis.

2. *Papilio angolanus*, *P. demodocus* (on manner).
3. Grasshoppers, *Cymatura bifasciata* (on manner).

P. angolanus and perhaps the *Cymatura* were eaten in preference to the leopard's meat before this had yet disagreed. With its evident disagreement may be compared the fact that it was only eaten by my carnivorous animals under stress of hunger.

The *Polyhirma*'s special defence had probably been much reduced by capture; the Lycoid bug was rejected more emphatically than the Bostrychid; the special defence of the *Laccotrephes* and the *Copris* are worth noticing, as also the fact that *Cryptacrus comes* var. *apicalis* is harder and so distinctly better protected against enemies in the manner shown by the experiment than typical *Cryptacrus comes*. I have always regarded them as distinct species.]

Exp. 130.—December 29. Persistently refused even to taste a *Laccotrephes ater*, but readily ate a *P. angolanus*, a *Mycalesis campina*, and a *T. brigitta*.

[This places the water-bug relatively to the roller below *P. angolanus*, if not below *T. brigitta*, apparently mainly if not entirely in virtue of its leathery covering.]

Exp. 131.—January 7, 1910. To place *Herpænia eriphia* and *Teracolus phlegyas*. After several grasshoppers, readily ate a *Mycalesis campina*, two large grasshoppers, another *Mycalesis*, a *P. angolanus*, and a *Teracolus phlegyas*, yet another grasshopper and three more *Mycalesis*. The next grasshopper was held for some time

and occasionally crushed before being finally swallowed, and the bird treated in the same way a *Mycalesis campina* and a *Papilio angolanus*. She then most obstinately refused to touch a *M. campina*, shook her head four or five times on being shown a *Teracolus phlegyas*, but nevertheless accepted, crushed slightly and swallowed it, again persistently refused to touch a *Mycalesis*, finally tasting it slightly and rejecting it, refused an *H. eriphia*, then barely closed her bill on an antenna and withdrew, refused with equal obstinacy a *P. angolanus*, refused in turn for a second or two, but changing her mind accepted and crushed and swallowed a *C. florella*, a *Teracolus phlegyas*, and an *H. eriphia*, again most obstinately refused *Mycalesis* and *P. angolanus*, but readily accepted a *Catopsilia florella*. The butterfly was seized only by a hindwing and on the bill cutting through this escaped and, finding an opening in the wire of the cage, flew away. The bird then accepted a *C. cloanthæ* with actual eagerness and at once swallowed it wings and all. Most of the butterflies in this experiment were offered with wings. She then persistently refused to touch any sort of grasshoppers, *P. angolanus* or *M. campina*, readily ate two of the termite-nest grubs disliked by the warblers, crushed well and rejected *P. lyæus*, refused without tasting a Lycænid with two wings attached and a *Spindasis natalensis*.

Five minutes later she readily ate a dead but fairly supple *H. eriphia*, but refused without tasting the *P. lyæus*.

Twenty minutes later she readily ate the Lycænid, but went on to eat also a *Mycalesis campina* and a *P. angolanus*.

[Order:—

- | | |
|----------------------|---|
| | $\left\{ \begin{array}{l} 1. \text{ } C. \text{ } florella, \text{ termite-nest grubs, and possibly } C. \text{ } cloanthæ \\ \text{and } H. \text{ } eriphia. \end{array} \right.$ |
| <i>T. phlegyas</i> . | |
| Grasshoppers. | $\left\{ \begin{array}{l} 2. \text{ } P. \text{ } angolanus. \\ 3. \text{ } M. \text{ } campina. \end{array} \right.$ |

H. eriphia probably above *P. angolanus*; and *P. lyæus*, at any rate, not preferred to *H. eriphia*.]

Exp. 132.—January 8. Tasted and rejected a *Zonocerus elegans* ♀, refused persistently to have anything to do with *Nychitona medusa*, tasted and doubtfully rejected a *Mylothris yulei*, crushed and threw away *Olapa nuda*, crushed and readily ate a *Terias senegalensis*, refused a saw-fly larva that is destroying the turnips, then tasted it with evident suspicion and threw it away. Its habits are quite conspicuous and its coloration, though very dull, is in contrast to the leaves it feeds on.

A little later after feeding on grasshoppers she accepted and ate four *Mycalesis campina* with two or three grasshoppers between each, the last two *Mycalesis* after at first refusing them. She then held a grasshopper for some time in her bill, crushing it occasionally, and finally threw it away, refused all others persistently without tasting, as also a *Mycalesis campina* and a *P. angolanus*, crushed and readily ate an *E. hiarbas*, again refused *P. angolanus* and accepted, but after crushing it threw away an *E. hiarbas*, eating, however, a *C. florella*.

[Probable order :—

1. *Catopsilia florella*.
2. *Eurytela hiarbas*.
3. *Papilio angolanus*, *M. campina*, grasshoppers.
4. *Mylothris yulei*, on manner above
5. *Zonocerus elegans* ♀, *N. medusa*, *Olapa nuda*, and the saw-fly larva.]

Exp. 133.—*January 9.* Offered a wasp, *Dielis 5-fasciata* var. *mansueta*. She at once accepted it, but failed to crush it at first trial, and the wasp at once escaped on the roller's relaxing her hold to bite again. The next wasp also escaped. The bird, in trying to prevent its escape, managed to get it rather far back in her bill and at once brought it hastily forward to the tip, when she again failed to crush it—it is a distinctly hard insect. A third having escaped in the same way, I offered the next with its two wings on one side cut off. But even this was dropped three or four times. Like its predecessors it stung furiously and continuously against the bird's hard bill while being held, and it seemed to me that the roller did not dare to bring it further back in her bill as she would have done an ordinary insect. The result was that, on her failing to crush the wasp at the first or second trial, she would either drop it completely or the insect, being held so near the tip, would escape on the roller's hold being momentarily relaxed to bite. Once it entered the bill abdomen first, but was at once rejected and no harm seemed to have resulted. The roller never followed it up when it fell, simply looking down at it lazily from her perch, so that I had to secure and reoffer it each time. On about the fifth occasion the roller cracked the insect's thorax at the first attempt, and at once abandoning all her previous caution merely ran it three or four times lengthwise through her bill as carelessly as she would have done a grasshopper, crushing it well as she did so, then turning it head foremost swallowed it. The bird evidently realized the danger from the sting, and her whole attention had been devoted each time to at once crushing the thorax of the insect in the point of her bill and especially to avoiding bringing it far back in the mouth. Once the thorax was crushed, she realized that there was little or no further danger.

She then tasted and at once rejected a *Galerucella triloba*, Fabr., and its larva and refused without tasting two species of *Mylabris* (*M. oculata* and *M. omega*, Mars.).

She was distinctly hungry, however, and made a huge meal off various Orthoptera and other insects which I now placed in the cage. Later on she crushed well and threw right away a Psychid larva enclosed in its usual caddis-like covering.

Exp. 134.—*January 9.* Later in the day :—

To ascertain whether *Discolia alaris*, Sauss., and *Dielis 5-fasciata* var. *mansueta* are unwelcome apart from their stings and the Psychid apart from its covering.

Was fed on grasshoppers till she refused to eat any more. She then equally persistently refused to touch a *P. angolanus* and crushed well and rejected a *Discolia alaris*. Only ten minutes later, however, she readily ate the *P. angolanus*, twice crushed and rejected the black wasp (*Discolia*), readily ate another *P. angolanus*

and a *Mycalesis campina*, refused the *Discolia* persistently without tasting, readily ate an ant-heap larva, and crushed and rejected a *Dielis* 5-fasciata var. *mansueta*. No fear had been shown of the wasp.

Five minutes later she again crushed thoroughly and threw away both wasps, refused persistently without tasting a very hairy Arctiid larva, ate four grasshoppers and refused the next three, but readily ate a *P. angolanus*, ate four more grasshoppers including those previously refused, crushed well and threw away *P. angolanus*, approached with suspicion the Psychid larva with "house" removed, tasted it slightly and rejected it, refused persistently to take the Arctiid larva or the Psychid larva reoffered. By no means yet replete.

[Probable order:—

1. Grasshoppers, *P. angolanus*, *M. campina*.
2. *Discolia alaris*, *Dielis* 5-fasciata var. *mansueta*, Arctiid larva.

The Psychid larva deprived of its covering was offered and rejected when *P. angolanus* was being refused, but the bird was still by no means replete.]

Exp. 135.—January 11. Readily ate one *Mycalesis campina* and three *Formicaleo leucospilus*, first crushing each slightly, pressed two or three times in her bill and flung right away a brilliant red millipede (*Spirolobus* sp.), crushed and rejected a small blue-black Phytophagous beetle, very readily ate another adult ant-lion, crushed and at once rejected a large green and yellow Phytophagous beetle, *Diacantha petersi*, readily ate a *Mycalesis campina*, crushed very thoroughly and finally rejected the dull bronze-green beetle, *Lagria villosa*, and readily ate another ant-lion. I then gave her a number of grasshoppers, after which she crushed well and rejected the ant-lion, accepted and ate a *Mycalesis campina*, took in the point of her bill, crushed slightly, and rejected an ordinary unswollen tick of our commonest species (*Rhipicephalus* sp.), ate five more grasshoppers large and small, the last three with disinclination and refused obstinately to touch any more, refused with equal obstinacy *Mycalesis campina* and *P. angolanus*, crushed thoroughly and threw away an Asilid fly, *Alcimus rubiginosus*, and crushed and flung away a Muscid fly that, sombre enough in colouring, is conspicuous through its habit of settling on the upper surface of large leaves in the forest; it seemed to me that she liked it less than the Asilid. She then refused even to taste an ant-lion, crushed well and rejected *P. lyæus*, first with wings, then without, readily accepted and ate *P. cebrene*, crushed well and rejected *E. hiarbas*, accepted a large *E. neophron* ♀ with all its wings attached, held it for a minute or two in her bill, crushing it at intervals, then tossed it away. As the action was indicative of disinclination rather than of dislike, I at once removed three of the wings and reoffered it, when it was at once readily crushed and eaten. The bird then accepted a *C. florella* with disinclination, crushed it, and dropped it.

Five minutes later she refused *Pap. lyæus* without tasting, readily ate two *Precis artaxia* ♂ f. and a *C. cloanthe* (this was held for a minute or two, the bird being replete), and then refused without tasting *C. cloanthe*, *P. artaxia*, *C. florella*, and *P. cebrene*.

[Probable order:—

- | | | |
|-----------------------|---|------------------------------|
| | 1. <i>Precis cebrene</i> , <i>P. artaxia</i> ♂ f., perhaps <i>C. cloanthæ</i> . | |
| | 2. <i>Alcimus rubiginosus</i> and <i>Papilio lyceus</i> . | |
| | 3. <i>M. campina</i> , grasshoppers. | |
| <i>P. angolanus</i> , | 4. <i>Formicaleo leucospilus</i> . | |
| Muscid fly, | 5. <i>Lagria villosa</i> , on manner above | } Cattle tick,
unbloated. |
| <i>E. hiarbas</i> . | 6. Scarlet millipede, Phyt. beetle 122, <i>Diacantha petersi</i> . | |

Exp. 136.—*January 12.* Crushed and ate a small green Phytophagous beetle (no smell and no exudation), refused, then tasted very slightly, and again refused a *Mylabris oculata*, definitely crushed and rejected another *Mylabris*, retreated from a ♀ *Zonocerus elegans* with very evident annoyance at its smell (sharp head-shakings, etc., which she at once indulged in whenever I brought it within two or three inches), refused persistently without tasting an undetermined beetle, crushed and threw away a bug, *Lygeus swynnertoni*, reached hesitatingly toward a large black millipede (*Spirostreptus* sp.), but retired with some slight display of horror on its commencing to squirm in the usual semi-spiral fashion, refused for a second, then tasted and rejected *Epilachna hirta*, refused persistently without tasting an *Aulacophora* sp., which doubtless reminded her of it, crushed thoroughly and ate a huge black Locustid of sluggish and conspicuous habits (*Mimnermus* sp.), and persistently refused without tasting a larval *Zonocerus elegans*.

Perhaps twenty minutes later she refused for a time, then, on my continuing to present it, definitely tasted and rejected the *Aulacophora*, which smells as strongly as any other of our Phytophaga, and accepted a small portion of the above-mentioned black millipede; but on her exerting pressure it slipped from her bill, being very hard and glossy. I therefore crushed it and reoffered it, when it was subjected to somewhat prolonged crushing and thrown away.

[The *Mimnermus* was preferred to the other insects used before the interval, and the millipede, after it, was shown more consideration than the *Aulacophora*. Its main defence, consisting in the emission of a pungently-smelling secretion, was doubtless lacking in the mere fragment offered.]

Exp. 137.—At noon, distinctly hungry once more, she did her best to crush a weevil (No. 128), even battering it well against the perch, but failed to make the least impression on it, and finally threw it away. She re-accepted it, but again failed to crush it though pressing with all her force, and threw it away, refusing to touch it again. However, she readily accepted, crushed, and swallowed another weevil (*Iphisomus* sp.), tasted and rejected a Chrysomelid, *Cladocera femoralis*, and crushed and swallowed *Horatopyga* sp. (similar but duller), readily ate after crushing it thoroughly a mantis egg-case and a *Mycalesis campina*, persistently refused to taste a *Mylabris oculata* or a ♀ *Zonocerus elegans*, and accepted doubtfully but then readily ate two fully gorged ticks of our commonest species.

[The *Iphisomus* was eaten readily and easily when 128 had proved impossible; the mantis egg-case, *M. campina*, and full-fed ticks were placed above *Cladocera*

femoralis, *Horatopyga*, and weevil 128, and the ticks over *Mylabris oculata* and *Zonocerus elegans*.]

Exp. 138.—In the evening I fed her on grasshoppers, etc., until she obstinately refused to touch another or a *P. angolanus*, but readily accepted, crushed and ate a weevil (*Iphisomus* sp.). A small Cetoniid, *Leucocelis ichthyurus*, did not crush easily, so was tossed away, but a Longicorn, *Cymatura bifasciata*, with pale yellow bars was subjected to a very prolonged crushing indeed and finally swallowed. The bird now became restless, moving up and down the perch and from one perch to another and frequently shaking her head. It seemed to me that she possibly regretted the acceptance of the *Cymatura*, but I had unfortunately not another to offer. It is noteworthy in any case that she accepted the *Cymatura* so readily, though she had when much hungrier refused *Mylabris oculata*; evidently such resemblance as exists between those two insects is only calculated to deceive at a distance. The bird then refused without tasting a cockroach and *P. cebrene*. She retained the appearance of being perturbed.

Ten minutes later, as she had settled back into her usual somewhat lethargic state, I reoffered the cockroach, which was crushed well and thrown away, the bird going on to eat with the greatest readiness an *Iphisomus*, a *P. cebrene*, and even a *P. angolanus*.

[The *Iphisomus* and *Cymatura bifasciata* (if not regretted) were preferred to the bitter grasshoppers, to *P. angolans*, and to *Leucocelis ichthyurus*, and the weevil at any rate was preferred also to the cockroach.]

Exp. 139.—*January 14.* Refused for a time, then tasted and rejected a driver-ant (*Dorylus* sp.) and thrice accepted an isopod, rolled up in a glossy, hard, black ball, which each time shot away from her bill as soon as pressure was applied. After the third failure she refused to touch it again, eagerly ate a *Mycalesis campina*, refused, then tasted, and at once rejected a *Mylabris oculata*, refused a *Zonocerus elegans*, showing a marked dislike to its smell whenever I brought it near.

She was now on an unaccustomed perch with no enlarged opening in the wire opposite for the admission of large offerings, and, as I could not tempt her away by showing it at the usual place, I had difficulty in getting to her a large dung-beetle, *Catharsius rhinoceros* ♀. On my dropping it from above she cleverly caught it in falling, but it slipped from her bill on her commencing to crush it, and I could not induce her to catch it again.

She then tasted and rejected *Alesia bidentata*, accepted a large *Xanthospilopteryx superba* with no smell at all, and subjected it to unusually prolonged crushing, in the course of which she several times half swallowed it, but at once brought it forward into the bill again and tasted it with redoubled care. Finally, after nearly swallowing it, she brought it up for the last time and threw it away and refused to taste it again. On my reoffering it with wings removed it was accepted, but evidently recognized by taste and was once more thrown away and ignored on re-presentation. The bird then refused a *Mylabris* (No. 22), but on my continuing to offer it tasted and rejected it, persistently refused without tasting a *Zonocerus*

elegans ♀, showing the usual suspicion of its smell, accepted, crushed and ate a small Cetoniid, *Leucocelis ichthyurus* (it slipped out of the point of the bill the first time, but on being re-offered was taken more firmly and easily crushed), readily accepted and swallowed a *Mycalesis campina*, and crushed without difficulty and ate a *Copris orion* ♂. It was rather a large specimen with an unusually projecting horn, and though it was seized well back in the mouth with the horn pointing upwards no sign of discomfort was shown during the crushing process.

[*M. campina*, *Copris orion* ♂, and *Leucocelis ichthyurus* were preferred to *Dorylus*, the isopod, *Zonocerus elegans* ♀, *Mylabris* 22, *M. oculata*, *X. superba*, *Alesia bidentata*, and *C. rhinoceros*, though *M. campina* and *C. orion* can perhaps hardly be regarded as fairly tested against any but the first two of these, and the *Catharsius* should have been further tried. The *Xanthospilopteryx* was at least far less obviously unpleasant than the others.]

Exp. 140.—*January 25.* Tried and rejected with signs of dislike two Phytophagous beetles, *Megalognatha rufiventris* and *Exosoma suturale*.

Exp. 141.—*January 31.* Very hungry indeed. Three or four times seized an *Anachalcos spectabilis*, but it each time slipped from her bill and she refused with an air of irritation to have anything more to do with it. She then crushed well and ate the Eumolpid beetle, *Corynodes dejeani*, as also *Megalognatha rufiventris* and *Exosoma suturale* (all three had been some days in pill-boxes and were doubtless not up to their full strength), tasted and at once flung away a Coccinellid, No. 84, ate after much crushing and some hesitation a Phyt. beetle, No. 145, with yellowish exudation (these two were freshly captured), refused a Coccinellid like it (*Epilachna 4-oculata*, Kolbe), at last leaning forward to it, but withdrawing again without tasting, refused without tasting a *Mylabris oculata* (♂), tasted with hesitation and rejected a *Danaida chrysippus* with wings, did her level best to crush a large weevil, *Brachycerus congestus*, but failed utterly, as she did twice again on re-presentation. After this she refused to have any more to do with it, but comparatively easily crushed and ate a *Copris orion* ♂.

[*Order of preference* :—

- (a) 1. *Corynodes dejeani*, *Megalognatha rufiventris*, and *Exosoma suturale* (all below full strength), and Phytophag 145 (fresh and juicy).
2. *Anachalcos spectabilis* (hard and rather glossy), Coccinellid 84.
- (b) 1. *Copris orion* ♂.
2. *Brachycerus congestus* (hard), *D. chrysippus*, *M. oculata* ♂, *Epilachna 4-oculata*, Coccinellid 84, and *Anachalcos spectabilis*.

The bird's great hunger must be kept in mind in assessing the probable value of the defences that caused refusal.]

Exp. 142.—*February 2.* Hungry. Offered a bright Buprestid, *Psiloptera cognata*, she accepted and tried to crush it, but the beetle at once slipped from her bill. This

happened four or five times, and the bird thereafter refused to touch it again. She had made no impression on it. She then accepted a Chrysomelid beetle (*Horatopyga*), but it is distinctly hard and slipped from the point of her bill as soon as pressure was applied. On my reoffering it, it was seized more firmly, crushed well without appreciable difficulty, and swallowed in spite of its rather strong smell. The bird then tasted and at once rejected a *Lycus*, probably *constrictus*, readily accepted, crushed, and ate another *Horatopyga*, tasted and rejected (after a refusal without tasting in each case) a *Mylabris oculata*, a Coccinellid No. 84, and a *Zonocerus elegans* (adult ♀), and readily accepted another *Horatopyga*. It was again, however, seized with the extreme tip of the bill and it slipped away, and I was unable to find it to reoffer it. I then gave her a number of grasshoppers, after which she readily ate a *P. angolanus*, a *Teracolus*, and, to my surprise, a *Terias*.

- [1. *Horatopyga* sp. (protected to some slight extent by hardness and gloss), bitter grasshopper, and perhaps *P. angolanus*, *Teracolus* sp., and *Terias*.
2. *Mylabris oculata*, Coccinellid (84), *Zonocerus elegans* ♀, *Lycus* prob. *constrictus*, *Psiloptera cognata* (hardness and gloss).]

Exp. 143.—Later in the day she readily ate a *Corynodes dejeani* (freshly captured), tasted and at once rejected a *Lycus*, probably *constrictus*, and refused persistently to taste a Coccinellid (84). I then placed a varied handful of Orthoptera, etc., in the cage, and the bird at once descended, ate a considerable number of them, and returned once more to her favourite perch apparently satisfied. She nevertheless readily ate ten more small grasshoppers which I picked out and offered by hand, refused, then tasted and rejected a *Terias*, but very readily ate a *Phrissura isokani* and a *Byblia*.

After five more grasshoppers she refused, then twice took in her bill and dropped an *E. hiarbas*, wings and all, being apparently very suspicious of it, or disinclined, but the third time definitely crushed it and swallowed it without further hesitation, refused *P. angolanus* without tasting, tasted well and swallowed a *Teracolus* (same sp. as other) with no sign of dislike, crushed well and swallowed the *P. angolanus*, accepted very readily and at once swallowed an *E. hiarbas*, refused, then doubtfully accepted, but ate a *B. severina*, took and rejected a *B. mesentina*, but on my reoffering it ate it, refused the next most persistently, as also a *Terias*, but readily accepted an *E. hiarbas*, refused for a few seconds, then took and dropped, but the third time definitely crushed and ate a *P. angolanus*, and after it readily nine small grasshoppers. Two more were eaten after a little coaxing, but the twelfth was finally and obstinately refused without tasting, as was also a *P. angolanus*. The roller then tasted and rejected a ♂ *P. demodocus*, refused without tasting a ♀ *H. misippus* with one hindwing attached, then twice took it from the forceps with an air of suspicion and each time slightly tasted and dropped it, refusing it after this without tasting, readily accepted and ate a *Precis clelia*, refused without tasting the ♀ *H. misippus*, and on my removing the sole remaining

wing tasted suspiciously and rejected the body. Five minutes later she again tasted and rejected it, crushed very thoroughly and rejected, but on my reoffering it again crushed and this time ate a cricket (No. 8) that rather resembles a longicorn—she was evidently doubtful about it,—crushed and rejected a biting fly (*Rhinomyza denticornis*) after showing distinct hesitation in accepting it, dropped a Cetoniid, *Leucocelis ichthyurus* (it had been seized in the tip of the bill and slipped out accidentally), but obtained a better grip on my reoffering it and crushed and ate it readily, again crushed and rejected the fly and refused it on my reoffering it, lost a second Cetoniid in the same fashion (I was unable to find it to reoffer), twice crushed very carefully and thoroughly and each time ended by throwing away a beetle, *Himatismus fasciculosus*, crushed and very readily ate a *Libythea*, refused, then tasted slightly and rejected the wingless ♀ *H. misippus*, but readily accepted, crushed, and ate a ♂ *C. florella*.

Fifteen minutes later she twice crushed well and rejected the ♀ *H. misippus*, crushed thoroughly—it was rather hard—and ate with apparent relish a Lycoid wasp, crushed and ate the *P. demodocus* that she had previously rejected, tasted very slightly and threw away the *H. misippus*, refused for a long time and finally crushed and threw away a *P. angolanus*.

Five or ten minutes later some more butterflies came in. I offered a *P. lyceus* which was accepted and eaten, as was, readily, an *E. hiarbas*. The bird then for some time refused to have anything to do with a *P. angolanus*, but finally accepted it, crushed, held it for some time, evidently undecided whether to eat it, and finally swallowed it, but refused the *H. misippus* without tasting.

A little later I fed her on very small grasshoppers, etc., till she would eat no more. She then for a long time refused *P. angolanus*, but finally crushed it slightly and threw it away, tasted slightly and rejected, but on my reoffering it crushed very thoroughly and very doubtfully ate a *P. lyceus* after having twice made as though to throw it away, again obstinately refused to taste *P. angolanus*, crushed and rejected an *Atella phalantha*, refused for a long time a *Hypolimnas wahlbergi* with a forewing attached, evidently regarding it with the greatest suspicion, then just took it in the point of her bill and dropped it without crushing, refused without tasting the wingless ♀ *H. misippus*, refused for a considerable time *P. cebrene*, being evidently replete, but finally accepted and ate it, refused, then once more barely tasted and rejected *H. wahlbergi*, and treated *Atella phalantha* in the same way.

[Lists:—

- (a) 1. Grasshoppers, *Phrissura isokani*, *E. hiarbas*, and probably *Corynodes dejeani*.
2. *Lycus* nr. *constrictus*, Coccinellid (84).
- (b) *Teracolus* sp. and *E. hiarbas* beside or just above *P. angolanus*, but latter placed more or less with *Belenois severina* and *mesentina*, though it may for the Pierines have been a matter of stimulation. *E. hiarbas*, grasshoppers, and *Precis clelia* above *Belenois severina* and *mesentina* and *Terias*.

- (c) 1. *Leucocelis ichthyurus* } *Libythea laius*,
 2. (On manner) Cricket 8. } *Catopsilia florella*.
 3. *H. misippus* ♀ and *Rhinomyza denticornis*. (The *Libythea*
 and *C. florella* above *Himatismus fasciculosus* too.)
- (d) 1. *Precis clelia*.
 2. *Papilio demodocus*, on manner.
 3. Lycoid wasp.
 4. *H. misippus* ♀.
- (e) 1. *Precis cebrene* and *Papilio lyceus* (*Precis clelia* above *Papilio angolanus*).
 2. *P. angolanus*, *Atella phalantha*, *H. misippus* ♀, and grasshoppers.
E. hiarbas and *P. demodocus* probably not below *P. angolanus*.]

Exp. 144.—*February* 3. Showed distinct suspicion at the loud and continuous crepitation of a beetle, retreating along the perch when I brought it near. The sound was probably associated with something nauseous or otherwise unpleasant in the roller's memory.

Exp. 145.—*February* 7. Inserted, scattered amongst her other food, three or four of the brilliant red-and-black, softish, nut-flavoured seeds of *Trichilia chirindica*. They were ignored. The experiment, to test whether birds recognise food instinctively, was therefore inconclusive.

Exp. 146.—*February* 10. I fed the bird on grasshoppers till she would eat no more. She then took a *P. angolanus* without alacrity, crushed it for quite a long time as though she could not quite make up her mind to eat it, then suddenly turned it head inwards and swallowed it. She refused the next, then listlessly took and crushed it and tossed it aside, proceeding to treat a ♀ *P. lyceus* in the same way. I next presented a powerful wasp, *Salix basalis*, black with yellow legs and wing-tips, but the bird showed much suspicion of it as it buzzed and struggled in the forceps, and though she several times seized it she dared not hold it long in her bill, but each time quickly crushed and threw it down. On my killing the wasp by crushing the thorax she continued to treat it in the same way and finally refused it altogether. She had doubtless tasted it, but the result was conceivably (though doubtfully) even now prejudiced by her fear of the sting.

She then refused to touch *P. lyceus*, regarded with some suspicion, but on my continuing to offer tasted and then very readily ate a wingless *Precis artaxia*, readily accepted a wingless ♀ *H. misippus*, held in the forceps in such a way that only the black upper surface showed, but after crushing and tasting it with great thoroughness threw it away, readily ate another wingless *P. artaxia*, tasted very thoroughly and finally threw away a wingless *H. wahlbergi*, tasted rather hurriedly four or five times the *Salix*, and each time dropped it with an air of suspicion or disinclination, again tasted well and rejected the *H. misippus* ♀ and the *H. wahlbergi* and, more promptly, the *P. lyceus*, and accepted, tasted, and made a number of unsuccessful attempts to swallow a small dull-coloured mantis (*Ligaria* sp.). The

creature, I found on looking closely, though inside the bill itself, had embraced the tip of the upper mandible with its claspers and was holding on tight. Finally, the bird flung it right away with an air of irritation. On my at once reoffering it, however, it was accepted very readily, crushed without a recurrence of the previous difficulty, and eaten.

[Order :—

1. *Precis artaxia* and *Ligaria*.
2. *H. misippus* ♀ and *H. wahlbergi* on manner above the Papilios.

Papilio lyæus, { 3. *Papilio angolanus*.
Salix basalis. { 4. Grasshoppers.

Interesting points were the probable force of the *Salix*'s sting (probably the wasp was otherwise unpleasant to some extent as well), the mantis's rather effective defence, and the thorough tasting of the two species of *Hypolimnas*.]

Exp. 147.—February 11. After a full feed of grasshoppers regarded a wingless body of *P. artaxia* with apparent suspicion and could not be induced to taste it.

Exp. 148.—February 12. Fed on grasshoppers till she would eat absolutely not one more, readily ate a *P. lyæus*, refused obstinately even to taste *P. angolanus*, tasted very thoroughly and threw away a ♂ *P. dardanus*, readily ate another *P. lyæus*, refused, then once more tasted and rejected *P. dardanus*, again refused to have anything to do with the *P. angolanus*, crushed well and rejected *P. lyæus*, but on my removing its one hindwing ate it fairly readily, as also three others without wings, the last two with a good deal of disinclination. She then leant forward to take a *Precis natalensis* ♂ f. with all four wings (underside shown), but drew back before tasting it in evident suspicion and with shakes of the head. I removed all but half a hindwing and reoffered it with the upper surface showing (to avoid exhibiting the white spots on a black ground), at the same time holding the forceps over the remainder of the red ground-colour. The bird accepted it readily, but the red that was displayed by the removal of the forceps quite possibly rendered her suspicious, for she at once paused and appeared doubtful whether to go on, then hesitatingly dropped it. On my at once reoffering it she accepted it doubtfully, but this time definitely crushed it and, evidently reassured, swallowed it. She then ate a wingless *Charaxes cithæron* ♀, obstinately refused to touch a *P. lyæus*, also without wings, rather more readily accepted, tasted well, and then ate without hesitation a *Precis natalensis* with one hindwing attached, very readily accepted and ate the next, dropped the next, as also a *P. artaxia*, and refused even to taste *Antanartia schæneia* and *Catacroptera cloanthe* (underside shown). Evidently replete.

Five minutes later she accepted with disinclination, crushed slightly, and dropped *Precis clelia* and *A. schæneia*.

Three minutes later she readily ate *C. cloanthe*, refused without tasting *A. schæneia*, the hindwing of which had now come off, readily accepted and ate *P. natalensis* ♂ f. and *P. artaxia*, refused without tasting *Atella phalantha* (with wings) and *Ant. schæneia*, readily ate a *P. tugela*, again refused the *Atella* and the *Antanartia*, but once more quite readily accepted and ate a *P. natalensis* ♂ f.

[Order :—

- | | |
|-----------------------|---|
| | 1. <i>Precis natalensis</i> ☉ f. and perhaps <i>Ch. cithæron</i> , <i>Precis artaxia</i> , <i>P. tugela</i> . |
| <i>A. phalantha</i> , | 2. <i>Papilio lyceus</i> .
3. <i>P. dardanus</i> ♂ perhaps on manner above
4. <i>P. angolanus</i> . |
| <i>A. schæneia</i> . | |

The initial attitude towards *P. natalensis* was very interesting, and suggests that even rarity—lack of practice—may be of use to a mimic under certain circumstances.]

Exp. 149.—*February* 13. Tasted and at once flung away a common blue frog-hopper, *Tettigoniella cosmopolita*, that settles conspicuously on the upper surface of large leaves and is fairly fearless; shook her head once or twice at a *Terias brigitta* with wings, but nevertheless accepted, crushed, and swallowed it, and accepted a brilliant metallic-green hymenopteron (*Chrysis* sp.). The wasp on being held by its wings in the forceps had adopted its usual plan of folding its head and thorax over into the hollow of its abdomen, and remained like this perfectly motionless while the bird endeavoured to crush it. She failed absolutely three times and each time ended by throwing the wasp away. The latter continued to lie motionless when rejected, and showed no sign of life even when I picked it up to reopen it. On the fourth occasion the roller succeeded in battering the wasp in two, but ended by rejecting it once more. That this rejection was due to the extreme toughness of the insect rather than to unpalatable qualities was shown by the fact that on my now reoffering one or other portion four or five times it was each time readily accepted and not rejected till the bird had made another attempt to batter or crush it. The covering of the abdomen was so intensely tough as well as hard that, when I squeezed it in from the sides, instead of breaking it would at once resume its former shape on the pressure being removed. The merest pressure on the sides of the separated abdomen served to extrude what looked like a sting, and in life the insect, though rolled up like an armadillo and in all other respects motionless, keeps darting this sting out (when held) now against the finger, now the thumb, in the most alarming manner.

After this incident I fed the bird up on grasshoppers till she would eat no more. She then refused, and on my coaxing her crushed and rejected a *P. angolanus* with one hindwing, and refused it without tasting on my removing this, crushed and tasted far more thoroughly and tried to swallow a *P. leonidas* with one forewing attached, but the wing kept getting in her way and she finally dropped the butterfly. On my reoffering it without the wing she ate it readily, but proceeded to do the same for a wingless *P. angolanus*.

- | | |
|-----------------------|---|
| | [1. <i>Papilio leonidas</i> probably definitely better than <i>P. angolanus</i> . |
| | 2. Grasshoppers. |
| <i>P. angolanus</i> . | 3. <i>Terias brigitta</i> , on manner, below grasshoppers.
4. <i>Tettigoniella cosmopolita</i> . <i>Chrysis</i> (failure). |
| | |

The incident of the hymenopteron illustrated well the value of toughness to such an insect.]

Exp. 150.—*February 14.* Hungry. Ate an unusually large feed of grasshoppers, refused the last, but ate a *P. angolanus* with one wing, ate two or three more grasshoppers, refused the next, but ate another *P. angolanus*, ate a few more small grasshoppers and a *P. lyæus*, then a few more and this time not only finally refused to eat any more Orthoptera, but also persisted in refusing to taste a one-winged *P. lyæus*, even when I had removed the wing. She nevertheless readily accepted and ate a *P. natalensis* ♂ f., persistently refused to taste a *Lachnoptera ayresi* with two wings, under surface shown, readily accepted and ate a *P. artaxia*, once more refused the *Lachnoptera*, but finally accepted, held it, tasted it well, though rather hesitatingly and with evident suspicion, and rejected it.

Five minutes later she once more obstinately refused it, ate a *P. cebrene*, and again refused to taste the *Lachnoptera*. I now cut off the remaining wings of the latter, all but a hindwing stump, and to this I applied the hindwing of a *P. cebrene*, holding it in place with the forceps while I reoffered the butterfly. The roller at once accepted it, but the *Precis* wing fell off as I withdrew the forceps, leaving the fulvous natural stump in full view. The bird certainly noticed it. She hesitated for a second or two, then carefully crushed the *Lachnoptera* and swallowed it, afterwards proceeding to taste and reject a wingless ♀ *P. lyæus* and readily ate a *Precis natalensis* ♂ f. and two *Rhopalocampta forestan*.

Five minutes later she as readily ate a third *Rh. forestan* and a *Rhopalocampta libeon*. None of these skippers possessed any appreciable smell.

[Order :—

1. *Precis natalensis* ♂ f., *P. artaxia*, probably *P. cebrene*, and perhaps *R. forestan* and *libeon*.
2. *Papilio lyæus*, *P. angolanus*, grasshoppers, and apparently *Lachnoptera ayresi*, so like *Atella* and probably taken for it, but its eating finally after a tasting perhaps less tinged with suspicion may indicate that it should go higher.]

Exp. 151.—*February 20.* Fed on grasshoppers, etc., rejected the last and refused obstinately even to taste any others. She then accepted and crushed a *P. lyæus* with one wing, held it for a considerable time and finally rejected it, refused it without the wing, refused for a time, then tasted with disinclination or suspicion and rejected a *P. natalensis* ♂ f., then similarly took a *P. clelia*, crushed it carefully, and rejected it too. I was unable to decide whether this was the result of repletion or of suspicion.

Five minutes later she took the *P. natalensis* again with suspicion or disinclination, crushed and held it for a few seconds and threw it away, then treated the *P. clelia* similarly, but ended by eating this, refused obstinately to taste the *P. natalensis* again, readily accepted a *Rhop. forestan* with wings, crushed it well and rejected it, accepted it again on my removing the wings, crushed and held it for some time, and finally swallowed it.

Five minutes later again she persistently refused even to taste the *P. natalensis*, very readily accepted, crushed, and ate a *Catopsilia florella* with only one wing, equally readily accepted a *P. cebrene*, but on crushing she paused, and having tasted it yet further, threw it away. Viewed with suspicion a wingless body of ♂ *C. florella*,

and ended by taking it from the forceps and at once flinging it aside, readily accepted another ♂, this time with one wing attached, and held and crushed it for quite a time, finally however dropping it, refused, then tasted carefully and rejected a *P. cebrene* and obstinately refused to touch a wingless *P. lyæus*.

Five minutes later she ate the *P. cebrene*, refused without tasting the *P. natalensis* and a wingless *C. florella*, again crushed very thoroughly before finally rejecting it a *C. florella* with one wing, tasted and rejected *Antanartia schæneia*, *P. tugela*, and *P. cebrene*.

Five minutes later she accepted a Tenebrionid beetle, *Amiantus globulipennis*, exerted some slight pressure on the thorax and threw it away, evidently too replete to go to much trouble over it, crushed and rejected an Elaterid beetle, refused obstinately to taste a house-fly (*Musca domestica*), readily accepted, crushed, and swallowed a Cetoniid, refused without tasting a weevil (*Lixus* sp.) covered with bright yellow powder, refused, then just took from the forceps and threw aside a *P. natalensis*, looked suspiciously at a *P. tugela* and would not try it, then accepted and ate a *P. cebrene* and the *P. tugela* after the usual crushing, but with no sign of dislike, tasted and rejected *Antanartia schæneia* and a fresh *P. natalensis* (♂ f., gravid ♀), also a wingless *C. florella*, of which she seemed to be suspicious, then refused without tasting a wingless *P. lyæus* and a *C. florella* with one hindwing.

Ten or fifteen minutes later she tasted and rejected *A. schæneia*, refused without tasting *P. natalensis*, readily ate *P. cebrene*, refused persistently to taste either *A. schæneia*, *P. natalensis*, or a *P. lyæus*, refused, then tasted suspiciously and threw away an *Iolais silas*, tasted and rejected *L. thalassina* ♂, refused without tasting *C. florella* and *P. angolanus*, tasted and at once rejected a ♂ *P. dardanus*, crushed much more thoroughly, apparently almost persuaded to eat it, a *P. lyæus* but finally threw it away too, refused for a second, then, changing her mind, accepted, crushed, and ate the original *P. natalensis*, crushed very thoroughly once more and this time ended by swallowing *P. lyæus*, refused, then tasted, and at once rejected *P. dardanus* ♂, and refused obstinately to taste the ♂ *L. thalassina*.

Five minutes later she crushed well and finally rejected *L. thalassina* ♂, refused, then tasted and rejected *P. natalensis*, obstinately refused to touch either *P. angolanus* or *P. dardanus* ♂, tasted very carefully, evidently inclined to eat it, *P. natalensis*, but then rejected it, crushed and ate a *P. lyæus*, refused persistently without tasting *P. natalensis*, *P. dardanus*, and another ♂ *P. lyæus*, but readily ate after crushing it a *Salamis anacardii* with one hindwing attached, obstinately refused to taste the *P. natalensis* disguised carefully with a *P. cebrene* hindwing instead of its own, at once and readily accepted an actual *P. cebrene*, crushed and swallowed it (showing, I thought, that she had noted the difference in the colour of the bodies), refused to taste a *Scarabæus nigroæneus*, refused, then barely tasted and tossed aside a common house-fly (*M. domestica*).

Twenty minutes later I myself crushed the *Amiantus* well and reoffered it. The bird appeared not at all to like the look of it, and after a certain amount of hesitation tasted it and threw it away, whether out of disgust for its mangled condition or because she actually disliked or suspected it I am unable to say.

[Order :—

<i>P. clelia</i> & prob	1. <i>Precis cebrene</i> , <i>Salamis anacardii</i> , <i>C. florella</i> , probably Cetoniid.	
<i>R. forestan.</i>	2. <i>Papilio lyæus</i>	} probably not a great difference.
<i>L. thalassina</i> ♂,	3. <i>Precis natalensis</i> , ☉ f.	
Grasshoppers.	4. <i>P. dardanus</i> ♂, <i>P. angolanus</i> .	
		<i>A. schœneia</i> . <i>P. tugela</i> . <i>A. globulipennis</i> . Elaterid, <i>Musca</i> <i>Lixus</i> . [domestica.

I felt at the time that the rejection of *Precis clelia* in the first paragraph of this experiment required some special explanation, as it was unusual for the roller to eat grasshoppers to *junonia*-refusing point, and an inclination had been shown to eat *P. lyæus*. I thought suspicion rather than repletion might account for the rejection—suspicion perhaps that *P. natalensis* had been the cause of ill-effects on some previous occasion and rejection of *P. clelia* through similarity of taste. The incident of the *Lachnoptera* of the other day might have been even more productive of suspicion, and the roller's ready discrimination between *P. natalensis* with a *cebrene* wing and actual one-winged *P. cebrene* was interesting in this connection. Certainly the whole experiment—the special mistrust of the wingless white body of *C. florella* and so on—rather conveys the impression of a bird in a suspicious frame of mind.]

CORACIAS GARRULUS. A.

Exp. 152.—*February* 21. Accepted doubtfully, but then crushed and ate readily enough a smallish snail (probably a young *Achatina*), tasted and rejected a Lycoid sawfly (*Athalia himantopus*), its larva (destructive to turnips, etc.), and a bug (*Bagrada hilaris*), tasted and rejected a *Zonocerus elegans* and a *Mylabris oculata*, and accepted with suspicion but then readily enough ate a large yellow slug (on turnips). Ten minutes later I offered a second slug, which was eaten as readily.

[Order :—

1. The yellow slug.
2. The Lycoid sawfly, imago and larva, *Bagrada hilaris*,
Zonocerus elegans, *Mylabris oculata*.]

Exp. 153.—*March* 1. Refused with shakes of the head, but on my pressing it on him tasted cautiously and refused to accept the larva of a Saturniid moth.

[Unfortunately nothing is stated as to the state of the roller's appetite.]

Exp. 154.—*March* 2. Very hungry. Attempted to eat a weevil, *Hipporrhinus chirindensis*, Mshl., but absolutely failed to crush it. After two or three attempts she refused to have anything more to do with it. Nevertheless, she crushed with comparative ease and swallowed a Tenebrionid (*Amiantus globulipennis*, Pér.). A dung-beetle, *Onthophagus panoplus*, was now seized, but was dropped with a shake of the head : from the position in which it had been taken I had no doubt that the

upstanding central horn had made itself felt. On my reoffering it, the bird leant round and seized it more cautiously, definitely avoiding the horn, then crushed and ate it and after it a second. Even this, however, was once suddenly dropped, and on my reoffering it the abdomen was battered off and eaten, and the thorax dropped and refused on being reoffered. The first had given some difficulty in swallowing.

[Order of ease:—

1. *Amiantus globulipennis*, Pér. ("comparative ease").
2. *Onthophagus panoplus* (the horn, which however is confined to the males, was the first time of use in securing rejection).
3. *Hipporrhinus chirindensis*, Mshl. (complete failure to crush).]

Exp. 155.—*March 2.* Hungry. Leant forward to take a Psychid larva, but finding apparently on closer inspection that it did not look tempting withdrew with a shake of the head. She immediately changed her mind, however, and tasted the Psychid, but tossed it aside. I then fed her on grasshoppers, etc., till she would eat no more. She now refused to taste a Cetoniid, *Neptunides polychrous*, tasted well and rejected a Cetoniid (*Heterorrhina alternata*, Klug) crushed by the bulbul yesterday (it was only just alive), tasted and rejected a Cetoniid, *Spilophorus plagosus*, with elytra removed before presentation, took but threw aside after but a lazy and ineffectual pressure on it a Tenebrionid, *Amiantus globulipennis*, seemed disinclined to accept *Nyctipao macrops*, deterred probably by the huge wings. She took it, nevertheless, battered off the thorax and swallowed the abdomen with one wing attached. On my reoffering the thorax with the remaining three wings she took it again with disinclination, and after holding it tossed it aside.

[Order:—

1. *Nyctipao macrops*, but not necessarily more than just preferred to
2. *Amiantus globulipennis*, *Spilophorus plagosus*, *Heterorrhina alternata*, *Neptunides polychrous*, and definitely placed very low, whether on the merits of the larva itself or only on account of its casing, the Psychid larva.

Nyctipao macrops was only eaten partly and with evident disinclination. The large wings were probably a strong deterrent to a bird barely hungry enough for the moth.]

Exp. 156.—*March 6.* I offered a *Neptunides polychrous*, holding it by the legs, when it suddenly opened its wings and commenced a great buzzing. This obviously alarmed the roller, who, when she finally did make up her mind to try it, attacked it as she would a wasp, seizing it, hurriedly crushing it and throwing it down. This happened three or four times, after which I removed the elytra and reoffered it. It was still taken with suspicion, but finally well tasted twice in succession and each time definitely rejected. The bird then tasted and rejected a *Mylothris yulei* and refused to taste a *Terias*, but readily ate a large number of grasshoppers (chiefly *Tryxalis* sp.). She finally refused most obstinately to touch another, though I

offered her at least eight comparatively pleasant species, readily ate an *Antanartia schœneia*, an *E. hiarbas*, and a large *Ch. candiope*, tasted and rejected *A. schœneia*, refused *Precis natalensis* ♂ without tasting, but finally crushed it slightly and rejected it, ate after a momentary hesitation an *E. hiarbas* but would have nothing to do with the next, tasted and rejected a *Pap. demodocus* with wings and without, afterwards refusing it without tasting, and ate most readily after crushing it slightly a ♂ *Aterica galene*. She then persistently refused a *Lachnoptera ayresi* and a *P. natalensis* ♂ f., but finally snatched each irritably from the forceps and gulped it down without an attempt at tasting it, and, after further refusals, an *Antanartia schœneia*. A *Pap. demodocus* was tasted more calmly and rejected, and a *Pr. tugela* crushed and readily eaten, but a *P. natalensis* ♂ f. was taken and just tossed aside and, on being reoffered, was snatched away and swallowed with an air of extreme irritation as before; also a *P. ceryne* (a rubbed ♂ specimen). *Pap. demodocus* was taken from the forceps and rejected, a *P. natalensis* eaten but the next rejected, and on re-presentation persistently refused. An *Atella phalantha* ♂ was similarly swallowed and the next rejected, but finally gulped down. A *P. natalensis* ♂ f. was refused persistently, as was an *Atella* with wings, but the latter was finally accepted and swallowed and the *P. demodocus* once more taken and rejected. Another *Atella* was knocked out of the forceps, then for a time refused and finally snatched away and hurriedly gulped down. A *Phrissura isokani* was most obstinately refused without tasting, an *E. hiarbas* after being for some time ignored was snatched irritably from the forceps and swallowed, as was also a *Pr. natalensis* ♂ f.; and the *Pap. demodocus* was again taken and thrown away. The bird was in a thoroughly irritable mood, but there was no mistaking the change when a *Ch. brutus* with one wing came on the scene. She took it with distinct eagerness and crushed and battered and swallowed it, obstinately refused to touch the *P. demodocus*, then ate a small grasshopper readily enough, but obstinately refused the next.

[The order would seem to have been roughly as follows:—

1. *Aterica galene*, *Charaxes brutus*, *Precis tugela*.
2. *Eurytela hiarbas*, *Antanartia schœneia*, *Atella phalantha*, *Precis natalensis* ♂ f., and *Precis ceryne*.
- Papilio demodocus*. { 3. The pleasanter grasshoppers and *Tryxalis* when many had been eaten in succession.
4. *Mylothris yulei*, *Terias*, and *Neptunides polychrous*.

Probably there is not much to choose between *Antanartia schœneia*, *Precis natalensis* ♂ f., *Precis ceryne*, and *Atella phalantha*, none of which butterflies were at all acceptable in the actual state of the bird's appetite.]

Exp. 157.—*March* 13. Fed on grasshoppers till she would eat no more, tasted and rejected *P. demodocus*, but crushed and readily ate a *Lachnoptera ayresi* (♀) and a *Salamis cacta*, var. *languida*.

Fifteen minutes later she crushed well and rejected a Reduviid bug, *Harpactor erythrocnema*, readily ate a *P. demodocus*, threw away an *Amiantus globulipennis*

after an irritable and not too strenuous pressure on its elytra, refused a hard weevil.

[Order:—

1. *Lachnoptera ayresi* (and *Salamis cacta*, if not merely a matter of special stimulation).

<i>Amiantus</i>	{	2. <i>Papilio demodocus</i> .
<i>globulipennis</i> .		3. <i>Harpactor erythrocnema</i> .]

Exp. 158.—*March 14.* *C. garrulus* battered a large, leathery, blackish slug with pale narrow dorsal stripe once or twice and threw it away. *Lanius collaris humeralis* tried to eat it, but was greatly bothered by the slime and rejected it finally without having injured it appreciably. The Bulbuls pecked at it, but getting their bills full of slime abandoned it. The Kingfisher (*Halcyon cyanoleucus*) banged it several times, and then rejected it. *Crateropus kirki* made a most prolonged attack, both shaking it about and hammering it with the point of its bill. It covered it with small scars, constantly desisting to clean its bill, but finally abandoned it altogether. All hungry, before food in morning.

[Evidently the slug was very low-grade, being protected efficiently both by its slime and its leatheriness.]

Exp. 159.—*March 15.* Crushed well and ate a *M. yulei*, battered very thoroughly and ate a *P. lyæus* larva, took with disinclination, crushed and rejected *M. yulei*, and twice refused, evidently regarding it with suspicion, but each time ended by accepting, crushing, and at once rejecting the larva of *Danaida chrysippus*, readily ate another larva of *P. lyæus*, and tasted with disinclination and rejected *M. yulei*.

[Order:—

1. Larva of *Papilio lyæus*.
2. Larva of *Danaida chrysippus*; *Mylothris yulei* (imago).]

Exp. 160.—*March 16.* Readily ate an *A. phalantha*, a *Terias*, and a *M. yulei*, tasted and rejected an *A. esebria* with wings, and refused obstinately even to taste a wingless *Danaida chrysippus*, then tasted doubtfully and rejected an *Amauris lobengula*, underside shown, very faded and at a little distance even a possible model for *P. angolanus*, and utterly refused to have anything further to do either with it or with a rather rubbed *P. angolanus* similarly offered. On my reoffering both after a short interval she again refused to touch the *Amauris*, but readily accepted and ate the *P. angolanus*.

[Order:—

1. *Papilio angolanus*.
2. *Amauris lobengula*.

Hungry enough after an *Atella phalantha* for a *Terias* and after a *Terias* for a *Mylothris yulei*, but refused the rubbed *P. angolanus*, possibly in mistake for a very rubbed *Amauris* (to test which possibility the experiment was carried out), but possibly not, as she discriminated between them a little later.]

Exp. 161.—*March 21.* Rejected an *H. missippus* ♂, but then also tossed aside a *P. cebrene*. [Experiment therefore not worth continuing, time being short, and the roller not hungry enough. The rejection of the *Hypolimnas* not necessarily indicative of low grade.]

Exp. 162.—*March 27.* Refused, then tasted, and at once rejected a black gregarious Lepidopterous larva, $\frac{3}{4}$ inch long, tasted and rejected the young green larva of *Gonimbrasia* sp. (of Feb. 4), crushed very thoroughly and several times seemed inclined to swallow the half-grown ($1\frac{1}{2}$ inches) but already magnificently decorated larva of *Gyanisa ethra*, but in the end rejected it, refused absolutely to touch the black larva or that of *Gonimbrasia* on re-presentation, again readily enough accepted that of *Gyanisa ethra*, but after much battering ended by again rejecting it. On my reoffering it, three or four times, it was each time taken but after some slight crushing or battering dropped. I now produced a full-grown Lepidopterous larva ($3\frac{1}{2}$ in. \times 0.7). The roller showed distinct fear or horror of it, drawing back and opening her bill and once or twice snapping at it viciously, and quickly withdrawing. Though I coaxed persistently I could not get her to touch it. She then tasted with disinclination and rejected a *B. mesentina* and a *Terias senegalensis*, ate readily a *P. angolanus*. A few minutes later she ate a *Bel. mesentina*, but threw a *T. senegalensis* right away and then refused to touch a second *Bel. mesentina* with such signs of dislike as seemed to indicate that the first had been eaten inadvertently or at any rate out of turn. She also again refused to touch the larva of *Gonimbrasia* (of Feb. 4), the black larva or the very large one, but readily ate a *P. angolanus* and a Passalid, *Eumelosomus zanzibaricus*, brown form, then leant forward and exerted a slight pressure on the elytra of an *Amiantus globulipennis*, and withdrew without attempting to take it from the forceps. But she ate with great relish, though with an occasional shake of the head—the result apparently of the strong pear-like smell,—a large bug, *Holopterna alata*.

[Order:—

- | | | |
|---|---|--|
| <i>Amiantus
globulipennis.
Terias sp.</i> | { | <ol style="list-style-type: none"> 1. <i>Holopterna alata</i>, <i>Papilio angolanus</i>, and (if its acceptance was not merely the result of the <i>Papilio</i>'s) <i>Eumelosomus zanzibaricus</i>. 2. <i>Gyanisa ethra</i>, half-grown larva. 3. <i>Gonimbrasia</i> sp., young green larva, also a black larva not yet identified. 4. Large larva, unidentified, regarded apparently with much dislike, as the result presumably of previous experience of itself or something like it. |
|---|---|--|

Though two of the moth larvæ have not been identified, their placing is worth stating for the indication it affords of the varying degrees of inacceptability that exist amongst such larvæ.]

Exp. 163.—*March 28.* Tasted and rejected ant No. 31, but readily ate a *B. mesentina*, wings and all,

Later. Hungry, tasted and rejected a large driver-ant (*Dorylus* sp.), and regarded with suspicion and rejected the larva of *Gonimbrasia*; the latter was barely tasted, simply taken and tossed away. She then refused to touch the black larva, refused, then tasted and rejected a *Mylabris oculata*, greedily ate a *B. mesentina*, several times took, crushed slightly, and threw away the large larva, tasted very thoroughly before rejecting it an *A. caldarena* both with wings and without, being evidently very nearly hungry enough to eat it, greedily ate a *M. yulei*, refused to taste a wingless *D. chrysippus*, again took the large larva (which had meantime been mauled by the shrike), tasted the wounded portion and rejected it, refusing to take it again, crushed and rejected the second ant (*Polyrhachis* sp.), refused to taste a *Zonocerus elegans*, then tasted and rejected a black fly (No. 19) and an earwig, also beetle (No. 154) common on turnips, but again eagerly ate a *B. mesentina*.

Later I fed her on grasshoppers till she positively refused to eat any more (she had eaten two or three abdomens after refusing the last complete grasshopper), crushed and rejected a wingless *H. misippus* ♀, readily ate a *P. angolanus* with wings, accepted doubtfully, crushed well and again rejected an *H. misippus* ♀ with all its wings, accepted doubtfully but having crushed it readily swallowed a *Teracolus eris* ♂, ☉ f., with wings, tasted and rejected a *B. severina* with wings, but greedily ate a second *Teracolus eris* (☉ ♂) also with wings, tasted with disinclination and rejected a *P. angolanus* both with wings and without, and twice a wingless *P. lyæus*.

Five minutes later she again accepted a ♀ *H. misippus* with wings, crushed it very thoroughly and carefully, and swallowed it wings and all, refused to taste a *P. angolanus* with wings or without, crushed and rejected the wingless *P. lyæus*, refused a second *H. misippus* with wings, but on my continuing to offer it crushed it slightly and threw it away, doing the same again when I had removed all wings but one; then refused to accept a *Pr. artaxia* or a *C. brutus*, each without wings, and on my continuing to hold them to it knocked each out of the forceps with the side of her bill. I reoffered the *Charaxes*, and she this time actually took it irritably in her bill, but finding it to be quite good crushed it well and swallowed it, and then crushed and swallowed the *P. artaxia* too. She then once more obstinately refused the *H. misippus* and finally knocked it out of the forceps, but readily—almost eagerly—accepted a *P. sesamus* ☉ f. with all its wings, crushed it and swallowed it, then refused to taste a *C. florella* with one wing.

[Order:—

(a)	(b)	
<i>Danaïda chrysippus</i> , <i>Polyrhachis</i> sp. <i>Zonocerus elegans</i> . Fly 19, Ant 31, Beetle 154, Earwig.	1. <i>Bel. mesentina</i> , <i>Myl. yulei</i> . 2. <i>A. caldarena</i> (on man- ner), large larva. 3. <i>Dorylus</i> , <i>Gonimbrasia</i> larva, black larva.	1. <i>Charaxes brutus</i> , <i>Precis artaxia</i> . 2. <i>Pap. angolanus</i> , <i>Te- racolus eris</i> ☉ ♂. 3. Grasshoppers, <i>H. misippus</i> , <i>Bel. severina</i> .
		} <i>Precis sesa- mus</i> ☉ f.
		} <i>Pap. lyæus</i> .

The *Teracolus* was eaten up to the refusal-point of the two *Papilios* (or itself spoilt the bird's appetite for these). *H. missippus* was also then eaten to a point at which the *Papilios* were refused, then itself refused.]

Exp. 164.—*March 29.* Obstinate refused to touch a ♀ *M. agathina* with practically no scent, refused, then tasted and rejected a *Terias senegalensis*, crushed and readily ate a *B. mesentina*, wings and all, just closed her bill on an *Amiantus globulipennis* and withdrew without a real attempt to crush it, crushed well, breaking it up, and threw away a dull-coloured beetle, *Scaptobius pentarthrius*, and refused it with shakes of the head on my reoffering it (certainly unpleasant), refused to have anything to do with a common large Coprid larva, ate a few small grasshoppers and finally refused persistently to take any more, twice crushed and rejected a dragon-fly, tasted and rejected an *E. hiarbas* with wings and a *P. angolanus* and a *P. dardanus* ♂ with only one wing, crushed and rejected a second dragon-fly, ate with disinclination a wingless *P. demodocus*, tasted and rejected one of the dragon-flies without wings, ate a *P. angolanus* again with disinclination, and now tasted and rejected a *P. dardanus* ♂ as also another *P. angolanus*, each wingless, crushed slightly and dropped a large ♀ *E. neophron*, but on my reoffering it crushed it more thoroughly and ate it readily, tasted and rejected a Carabid, *Polyhirma bilunata*, Boh., and refused to touch a small Tipulid fly.

[Order:—

<i>Belenois mesentina</i>	
(not tried, however, against the last three insects in "4").	
1. <i>Euphaedra neophron</i> .	
2. <i>Papilio demodocus</i> (with disinclination).	} <i>Papilio angolanus</i> .
3. Grasshoppers.	
4. <i>Terias senegalensis</i> , <i>Mylothris agathina</i> , <i>Am. globulipennis</i> , <i>Scapt. pentarthrius</i> , Coprid larva.	} <i>Papilio dardanus</i> ♂. Dragon-fly 10. <i>Eurytela hiarbas</i> .]

Exp. 165.—*March 30.* Hungry. With a few minutes' interval between each, crushed and rejected with dislike two separate hive-bees, readily ate a *B. mesentina*, refused, then tasted and threw away a *Terias senegalensis*, refused to touch another hive-bee (I had killed each bee before offering it), crushed and rejected two dragon flies, crushed and readily ate another *B. mesentina*, refused to touch a different wingless dragon-fly or a *Terias senegalensis*, tried an *Amiantus globulipennis* in her bill, but, finding it hard, threw it away.

A little later she crushed well and swallowed a beetle, *Himatismus fasciculosus*, refused, then accepted, crushed and swallowed a *T. senegalensis*, refused, then crushed and threw right away a hive-bee and obstinately refused to touch a dragon-fly. Later again she refused, then tasted and rejected a ♀ *M. agathina*, very readily ate a *T. senegalensis*, crushed well and again threw away the *Mylothris*, still with all its wings, tasted and at once rejected it with only one wing, accepted a ♂ *Neptunides polychrous* and tried to crush and batter it, but the beetle was tough and slippery

and struggled violently, its sharp clinging claws frequently reaching the roller's lores and causing its hasty rejection. The bird each time readily accepted it again and had another try, but finally became irritated beyond measure and would have nothing more to do with it. The beetle was not greatly the worse for its experience. She then accepted an *Amiantus globulipennis* and tried for a few seconds to crush it by sheer bill-pressure, but, failing, threw it away, then crushed and readily ate two brown *Phytophaga* (*Horatopyga* sp.) each with its normal smell. The first of these I thought might have slipped down by accident without having been properly crushed, the second was well crushed. She finally crushed well and rejected a locust, *Taphronota calliparea*, that was exuding a quantity of froth. Butterflies in this experiment were offered wings and all.

[Order :—

- | | | | | |
|--------------------------|---|---------------------------------|---|--------------------------|
| <i>Horatopyga</i>
sp. | { | 1. <i>Bel. mesentina</i> . | } | Hive-bee,
dragon-fly. |
| | | 2. <i>Terias senegalensis</i> . | | |
| | | 3. <i>Myl. agathina</i> ♀. | | |
4. *Amiantus globulipennis* and *Neptunides polychrous*, each probably better defended (the former by hardness, the latter by claws, fighting weight, &c.) than *M. agathina* ♀ by nauseousness, *Taphronota calliparea* probably not better than *Horatopyga*, *Himatismus* not necessarily better than *Terias senegalensis*, and hive-bee and dragon-fly probably not better.]

Exp. 166.—April 8. Refused, then tasted, and rejected an *M. agathina* ♀, very readily ate after crushing it a *B. mesentina*, subjected to slight pressure and tossed aside a Tenebrionid beetle, *Psammodes mashunus*, Pér., refused to touch a grey isopod smelling of almond, an orange-coloured centipede (*Scolopendra morsitans*), a blister beetle, *Mylabris oculata*, or the *Mylothris* reoffered, very readily accepted and swallowed a *B. mesentina*, refused to touch a *Psammodes* sp., evidently regarding it with marked suspicion, pressed with her bill and threw aside a *Psammodes perfidus* and again *P. mashunus*, refused, then tasted slightly and rejected the grey isopod, definitely tasted and threw away the orange centipede, refused again to touch the *Mylabris oculata*, readily accepted and ate a *B. severina*, and once more refused *Mylothris agathina* ♀. The unidentified *Psammodes* had probably reminded it of an *Anthia*.

[Order :—

1. *Belenois mesentina* and *B. severina*.
2. *Mylothris agathina* ♀, *Mylabris oculata*, grey isopod (unbroken), *Scolopendra morsitans*, *Psammodes perfidus*.]

Exp. 167.—April 10. Readily accepted and ate a *B. mesentina*, refused, then accepted and ate with disinclination a *Terias brigitta*, readily accepted and ate another *B. mesentina*, tasted and threw away a frog-hopper, refused to touch an *Epilachna chrysomelina* or a *Mylabris oculata*, readily ate a *B. severina*,

crushed and rejected a large grey isopod with almond smell, also an orange-coloured centipede (*Scolopendra morsitans*), readily ate another *B. severina*, tasted and rejected a Tipulid fly, refused to taste a frog-hopper and a *Psammodes* sp., then again crushed and rejected the Tipulid and a *Galerucella triloba*. Ten minutes later she tasted and rejected a Syrphid fly (*Rhingia corulescens*), but readily ate a large number of small grasshoppers. She now refused, then tasted slightly and rejected a *B. severina*, crushed well and rejected a *Diphrontis vethi*, refused without tasting a *Himatismus fasciculosus*, readily ate an *E. hiarbas* and a *Neptis swynnertoni* (both with wings), refused to accept a Locustid, *Enyaliopsis petersi*, after having very cautiously tasted the abdomen, and readily accepted and ate a *P. angolanus* with one wing. *Belenois* in nearly all experiments nowadays is offered with all its wings attached.

Later in the day I gave the roller grasshoppers till she accepted them with disinclination. She then crushed and readily ate a ♀ *H. misippus* with one wing, crushed well and rejected a *P. angolanus* with one wing and just took it, crushed it slightly, and threw it away on my reoffering it with the wing removed, barely tasted and tossed aside a *P. lyæus* with one wing, crushed and readily ate an *H. misippus* ♂ with one wing, crushed and rejected a *C. florella* and very readily accepted and ate a *P. natalensis* ♂ f. She then tasted with disinclination and rejected a *P. dardanus* ♀ f. *hippocoon* and an ant-lion, a wingless *P. demodocus* and a *C. cloanthe* ♀.

[SUMMARY:—

- | | | | |
|---------------------------------|---|--|---|
| (a) | 1. <i>E. hiarbas</i> and <i>P. angolanus</i> . | (b) | 1. <i>P. angolanus</i> . |
| | 2. <i>Himatismus fasciculosus</i> . | | 2. <i>Enyaliopsis petersi</i> . |
| | (c) | 1. <i>Diphrontis vethi</i> , grasshoppers, <i>E. hiarbas</i> , <i>P. angolanus</i> . | |
| Tipulid and
<i>Rhingia</i> . | } | 2. <i>B. mesentina</i> and <i>severina</i> (assuming them to be equal). | |
| <i>Psammodes</i> . | | 3. <i>T. brigitta</i> , frog-hopper, <i>Epilachna chrysomelina</i> , grey isopod, | |
| <i>Galerucella triloba</i> . | | orange centipede. | |
| (d) | 1. <i>H. misippus</i> ♂ and ♀. | (e) | 1. <i>Precis. natalensis</i> ♂ f. |
| | 2. Grasshoppers, <i>P. angolanus</i> and
<i>P. lyæus</i> . | | 2. <i>C. florella</i> (not better than
<i>H. misippus</i>). |

Papilio hippocoon, *P. demodocus*, *C. cloanthe*, and ant-lion not better than *Precis natalensis* ♂ f.]

Exp. 168.—April 20. Very hungry. Twice, with a 5-minute interval between, crushed and rejected a large grey maggot-fly (*Sarcophaga* sp.), very readily accepted, crushed and ate *B. severina* with wings, again tasted and rejected a Tipulid fly and a *Mylabris oculata*, readily ate a gravid *M. agathina*, wings and all, tasted and rejected the fly and an *A. neobule* with one wing, refused to taste an *Epilachna hirta*. Fifteen minutes later she refused, then tasted and rejected, the fly and readily ate another *B. severina* with wings.

[Probable order:—

1. *Belenois severina* and *Mylothris agathina*, gravid ♀.
2. *Sarcophaga* sp., the Tipulid, and *Mylabris oculata*, also perhaps *A. neobule* and *Epilachna hirta*.]

Exp. 169.—April 25. Tried and rejected weevil 187, readily accepted and ate *Mylothris rueppelli*, tried and rejected a *Psammodes perfidus*, also some gnats, and refused a *Belenois*.

[Order :—

1. *Mylothris rueppelli*.

2. Weevil 187.

Nothing definite can be deduced with regard to the remaining insects.]

Exp. 170.—April 27. Hungry. Tried and rejected two weevils (No. 187 and 146), tasted and rejected No. 120, very readily ate *Belenois severina*, tasted and rejected a house-fly and a hive-bee, also *Mylabris oculata*, readily ate *Odynerus vulneratus*, tasted and rejected once more the house-fly and the hive-bee, and readily ate ♀ *Mylothris agathina*, wings and all.

[The order (allowing for the known relative position between the *Belenois* and *Mylothris*) was : firstly, *Belenois severina*, *Mylothris agathina* ♀, and *Odynerus vulneratus*; and, secondly, weevils 187 and 146, 120, house-fly, hive-bee, and *Mylabris oculata*.]

Exp. 171.—September 20. Found eating grasshoppers hungrily. Tasted and rejected a stalk-eyed fly (*Diopsis*), readily ate *Henotesia perspicua*, refused the fly, crushed and readily ate *Byblia ilithyia*, refused the fly, eagerly ate *P. angolanus*, again refused the fly, but ate with avidity 12 medium-sized grasshoppers and another *P. angolanus*. I had nothing of a lower-grade nature to offer.

[*Henotesia perspicua*, *Byblia ilithyia*, *Papilio angolanus*, and grasshoppers were distinctly preferred to the *Diopsis*, and the number of grasshoppers and butterflies eaten after its first refusal were considerable (16), showing appetite.]

Exp. 172.—September 29. Hungry. Inspected and refused to touch *Musca domestica*, readily accepted and ate a *Terias brigitta*, tasted well and rejected a large bluebottle (*Calliphora*), again readily ate a *T. brigitta*, tasted and rejected a *Musca domestica*, and refused without tasting a bluebottle, afterwards tasting well and rejecting a fruit-fly. After a number of grasshoppers she tasted and at once flung away an *A. rahira*, readily ate a *P. angolanus* and a *N. agatha*, and refused to touch the *A. rahira* (all of them wings and all).

[The pleasanter grasshoppers, *Papilio angolanus* and *Neptis agatha* were preferred to the fruit-fly, and the latter (on manner) to *Musca domestica* and *Calliphora*. *A. rahira* was placed below *P. angolanus* and *N. agatha*.]

Exp. 173.—November 23. Refused, then tried and rejected, *Chrysops wellmanni*, and readily ate in preference to it a small dull grasshopper and *P. angolanus*, refused, then tried and rejected, *M. agathina* ♀.

Exp. 174.—December 2. Tried and rejected *Aletis monteironis*, ate readily in preference to it a Tenebrionid beetle, *Micrantereus vicarius*, and, more slowly, a cockroach, *Gynopeltis cryptospila*, tried and rejected emphatically a grasshopper (*Euprepocnemis* sp.).

Exp. 175.—*December 4.* Tried and rejected a grasshopper, but ate readily, crushing it easily, an isopod, a smallish individual.

Exp. 176.—*December 5.* (After grasshoppers.) Refused without tasting, then tried and rejected a grasshopper (*Catantops* sp.) and *Aletis monteironis*, ate readily *Mycalesis campina*, tried and rejected *Terias senegalensis*, tried and rejected a big *Acridium lineatum*, and battered very thoroughly a huge horny Longicorn, *Mallodon downesi*, but failed repeatedly to swallow it, the head and thorax being the difficulty. She finally battered these off and swallowed the rest, tried and rejected the head and thorax reoffered. Later she threw away a large Coprid larva, but ate readily that of a Cetoniid beetle, *Rhabdotis aulica*.

[Order :—

1. Larva of *Rhabdotis aulica*.
2. *Mallodon downesi* (thorax and head the difficulty).
3. *Acridium lineatum* (interesting that evidently regarded as less easy than the big Longicorn), *Terias senegalensis*, *Aletis monteironis*, and *Catantops*.

The *Mallodon* had been found moving sluggishly about in the forest.]

Exp. 177.—*Later.* Hungry, just before noon. Tried and rejected a grasshopper (*Catantops*), a moth (*Syntomis cerbera*), and a grasshopper (*Atractomorpha*), but readily tackled a very frothy *Taphronota calliparea*, banging it for several minutes and several times commencing to swallow it before finally throwing it away. She then readily ate an Asilid fly, *Alcimus rubiginosus*, three grasshoppers, three larvæ of *Rhabdotis aulica*, another Asilid, and a *Mycalesis campina*, a large grasshopper (*Xiphocera*), then yet another Asilid and a *P. angolanus*.

[*Alcimus rubiginosus* was preferred to *Taphronota calliparea*, and the latter certainly tempted the roller more than *Syntomis cerbera* and the two grasshoppers. It is even probable that *M. campina*, *P. angolanus*, and the large grasshopper (*Xiphocera*) were also preferred to *Taphronota*, but the complicating factor of possible special stimulation is unfortunately present.]

Exp. 178.—*December 6.* After a few grasshoppers. Ate readily a beetle, *Anomala ustulatipes*, and a bug, *Echinocoris* sp., but also a *Terias senegalensis*, failed to crush and abandoned a weevil, *Brachycerus congestus*, refused without tasting a house-fly (*M. domestica*), then took and swallowed it, tried and rejected *Acraea caldarena*.

[Probably very hungry to have eaten the house-fly (which she has already placed lower than *Terias*), and this gives a partial measure of the difficulty presented by *Brachycerus congestus*.]

Exp. 179.—*December 10.* Tried and rejected large green fly (*Pycnosoma*), an Anthomyiid fly, large brown fly, house-fly and another fly (*Anthomyia*), and refused persistently without tasting *Zonocerus elegans*, ate readily in preference to all these *Terias senegalensis* and a black Cetoniid (*Diplognatha gagates*).

Exp. 180.—*December 11.* Refused without tasting a housefly and the following flies :—*Morellia prolectata*, *Anthomyia* sp., *Pycnosoma* sp., and an Anthomyiid, ate readily *Alcimus rubiginosus*, tried and rejected a hive-bee twice, tried and rejected *Mylabris oculata*, again persistently refused without tasting all the above flies, seized a large Carabid, *Tefflus hacquardi*, but at once threw it away and remained gasping on her perch for a couple of minutes, then ate readily a grasshopper (*Catantops*), tried and rejected and then persistently refused without tasting a hive-bee, refused persistently without tasting all the above flies, tried and rejected *Zonocerus elegans*.

Later, refused emphatically without tasting, then tried and rejected a fly (*Pycnosoma chloropyga*), persistently refused without tasting a house-fly, refused without tasting, then tried very thoroughly and finally rejected, a Syrphid fly, doubtful. She then persistently refused without tasting a hive-bee, ate readily an Asilid, *Microstylum validum*, refused without tasting, then tried and rejected, the Syrphid, refused emphatically, then barely tried and rejected without tasting another fly, ate readily *Alcimus rubiginosus*, readily ate nearly 40 grasshoppers mostly small, refused to touch any more, ate readily *Alcimus rubiginosus*, refused quite decidedly without tasting it the Syrphid.

[In the first experiment *Alcimus rubiginosus* was preferred to the various other Diptera used, as was grasshopper 47, and the latter was also preferred to *Mylabris oculata*, *Tefflus hacquardi*, and hive-bee, against which three insects the *Alcimus* was not pitted.

In the second experiment *A. rubiginosus* was preferred to house-fly, *Pycnosoma chloropyga*, the Syrphid (itself probably preferred to the other two), and to hive-bee, and *M. validum* was preferred to all but one fly, against which it was not pitted. The fact that nearly 40 grasshoppers were eaten after the last of the rejections shows how low the insects involved must be placed.]

Exp. 181.—*December 15.* Hungry. Ate readily a moth, several grasshoppers, another moth, tried well and rejected an Ortalid fly (*Peltacanthina stictica*), ate readily a third moth, refused emphatically and persistently without tasting it a housefly, tried and rejected a *Hematopota* near *brunnescens*, ate readily a *Terias regularis* captured on the Gambadziya and a moth, and tried and rejected a blister beetle, *Mylabris oculata*. She then ate several grasshoppers—all to-day have been eaten with disinclination—and refused any more, ate readily one of each of the three Lycænids, a *Mycalesis campina*, and a *Terias senegalensis*, but then went back to grasshoppers.

Later, having been fed on grasshoppers till she refused more, ate readily *Phrissura isokani*, tried and rejected *Alena nyassa*, and then three Lycænids, also the moth and *Hematopota* near *brunnescens*, and refused without tasting a fly (*Peltacanthina stictica*) and a housefly, tried and rejected a *Teracolus* and a *Terias*, ate very readily a *Pap. angolanus*, and once more refused the rest without tasting.

[Order :—

1. *P. angolanus*.

- | | | |
|---------------------------------|---|---|
| <i>Alena</i>
<i>nyassa</i> . | { | 2. Moth, the three <i>Lycænids</i> , <i>Terias regularis</i> (and probably <i>T. sengalensis</i> , <i>Myc. campina</i>), grasshoppers.
3. <i>Hæmatopota</i> nr. <i>brunnescens</i> , housefly, <i>Peltacanthina</i> , <i>Mylabris oculata</i> . |
|---------------------------------|---|---|

Phrissura isokani was eaten in preference to grasshoppers, but not tested against the rest, though it is probably not lower than the *Alena*, refused just after its acceptance.]

Exp. 182.—December 27. Readily ate *Belenois mesentina* and three grasshoppers, then tried and rejected scented Longicorn (*Closteromerus viridis*), ate readily *B. mesentina*, twice failed with a Buprestid, *Psiloptera cognata*, it glancing out of her bill each time.

[*Closteromerus* and the *Psiloptera* (in virtue of hardness and gloss) below *B. mesentina*.]

Exp. 183.—January 8, 1911. Fairly hungry, crushed without any great difficulty and ate a dung beetle, *Catharsius rhinoceros* ♀. The thorax with elytra attached fell away during crushing.

Crushed and ate a round forest "woodlouse" isopod.

Exp. 184.—January 10. Fairly hungry. Refused decidedly without tasting a blister beetle, *Lytta thoracica*, then took a Locustid, *Enyalipsis petersi*, by the thorny thorax exuding juice, pressed it, and threw it away, refusing to have any more to do with it.

Exp. 185.—January 12. Fear of owl. A barn-owl (*S. flammea*), dead, but with eyes open and held in a life-like position, was shown to the birds to-day. Roller indifferent.

Exp. 186.—January 13. Fairly hungry. Pressed a dung beetle, *Gymnopleurus fastiditus*, and as it did not yield threw it away. The same with a second. But a *Micrantereus vicarius* crushed more easily and was swallowed. She then tried and rejected, failing to crush it, a large weevil (*Brachycerus*), but accepted an *Enyalipsis petersi*, which she battered into a pulp and swallowed. She kept closing her eyes or drawing the nictitating membrane across as she did so, but I think that it was only when one of the locust's tarsi approached an eye, and not in consequence of the latter's unpleasant qualities.

[*Enyalipsis petersi* and *Micrantereus vicarius* less well protected relatively to the roller than *Gymnopleurus fastiditus* and the *Brachycerus*.]

Exp. 187.—January 14. Alarmed at a large live Amphisbænid, but only very moderately so. [To test knowledge of harmlessness.]

Exp. 188.—February 1. Tried and rejected an *Amauris albimaculata*. Refused without tasting *Acræa johnstoni*.

[A mimicry experiment.]

Exp. 189.—*February 27.* Very hungry, readily ate an *A. johnstoni* and an *A. igola*, refused without tasting *A. caldarena*.

Exp. 190.—*March 1.* Kept longer than usual without food and very hungry, readily ate after crushing it an *A. igola*, red ♀, tried and rejected *A. caldarena* and a second *A. igola* (♂), readily ate, after crushing it, an *A. johnstoni*, and refused, then tasted slightly, and rejected the *A. igola* ♂ reoffered.

After a full-grown larva of *Rhabdotis aulica* she refused most emphatically and persistently without tasting it *A. esebria* (a slightly buffy-white ♀), *Nyctemera leuconoë*, *A. lobengula*, and *A. albimaculata*.

A little later (she had fed well meantime) she refused a *P. lyceus* and a grasshopper 1061, then refused, tasted slightly and rejected first a *Pitthea continua*, then a *Papilio echerioides* ♂, and thereafter refused to touch them again, refusing with equal persistence to taste an *Antanartia schœneia*, an *E. hiarbas*, and a *Charaxes natalensis*. All were offered with their upper surface fully displayed. On my offering them with the *under* surface up, the moth was still refused but the *Antanartia* readily accepted, though thrown away after thorough tasting. The *P. echerioides* ♂ and the *E. hiarbas* were persistently refused, but the *C. brutus* accepted, eagerly crushed, and swallowed.

[SUMMARY:—*A. johnstoni* was preferred to *A. igola* ♂ and to *A. caldarena*, and the latter at any rate not liked appreciably better than *A. igola*. At this point of considerable hunger very little feeding produced a refusal of *A. esebria* ♀, *N. leuconoë*, *A. lobengula*, and *A. albimaculata*, all of which might, therefore, be presumed to be low-grade. *C. brutus natalensis* was preferred to *A. schœneia*, *E. hiarbas*, *P. echerioides* ♂, *P. lyceus*, *Pitthea continua*, and grasshopper 1061. A good mimicry experiment, the bird distinguishing by their under surface butterflies resembling each other on the upper surface.]

Exp. 191.—*March 2.* I fed the roller on meat (the lights of a freshly killed sheep) till he would eat no more; he persistently refused the last piece with shakes of the head; then offered a *Terias senegalensis* and a *M. yulei*, both of which were accepted and eaten, though an *A. johnstoni* was refused. She then refused to touch an *A. dominicanus*, or, after it, a black and white ♀ *A. esebria*, cautiously tasted an *A. neobule* and rejected it, thereafter refusing persistently to touch either it, a bright ♂ *M. igola*, or a ♀ *A. doubledayi* with a slightly clear-wing appearance, refused to taste either a *Nychitona medusa* or a *Redoa melanocraspis*, both, as also the preceding offerings, offered with wings spread and upper surface shown. Ate two grasshoppers, then persistently refused to touch a *M. rueppelli* or a *Mylothris-mimic*, but accepted hesitatingly, then readily ate, a *Phrissura isokani* ♂.

[*T. senegalensis* and *M. yulei* were preferred to the meat, and, at any rate, probably not liked less than *A. johnstoni*, *A. dominicanus*, *A. esebria* ♀, *A. neobule*, *A. igola* ♂, *A. doubledayi* ♂, *L. medusa*, and *Redoa melanocraspis*. ♂ *Phrissura isokani* was preferred to *M. rueppelli*, and was tried, though hesitatingly, where a more definite mimic was refused. It was perhaps of interest that *A. neobule*, the first of its colour to be offered, was tried, while the second, *A. doubledayi* ♂, with a clear-wing appearance, was refused.]

Exp. 192.—*March 3.* Had fed not long before. Refused to touch meat or a *Terias brigitta*, then tasted slightly and refused the latter. Tasted and rejected an *A. phalantha*, and refused to touch it again, refused persistently to taste a *Lachnoptera ayresi*, offered similarly with upper surface displayed, and refused both butterflies offered to show the under surface only, again refused the *Terias*, accepted and crushed a *Mycalesis campina*, but then threw it away, readily ate a *P. angolanus*, tasted and rejected a second *Atella phalantha*, without wings, accepted hesitatingly, but, having tasted it, readily enough ate a *Lachnoptera ayresi*, also wingless, and again tried and rejected the wingless *Atella*. She next crushed and flung away a *Cyclopides metis* and refused thereafter to touch either it, a *Padraona zeno*, or a *Kedestes chaca*, all offered with the upper surface displayed. On my reoffering them with only the under surface shown, she refused the *C. metis*, tasted rather hesitatingly and ate the *K. chaca*, tasted, though with hesitation, the *Cyclopides* and once more flung it away, accepted, crushed and readily ate the *P. zeno*, ate a *Leuceronia thalassina* ♂, hesitated over an *E. hiarbas* but decided not to take it, accepted, pressed with her bill, and threw away a *Dielis 5-fasciata* (the rejection was due, I thought, at least partly to its hardness), refused to touch again either it or two other wasps. Tasted and rejected a yellow-legged wasp (*Salix* sp.) and readily ate a small grasshopper.

[SUMMARY :—

- | | | | |
|-----|---|-----|---|
| (a) | 1. <i>L. ayresi</i> , <i>P. angolanus</i> . | (b) | 1. <i>K. chaca</i> and <i>P. zeno</i> ; perhaps |
| | 2. <i>A. phalantha</i> , <i>T. brigitta</i> , <i>M. campina</i> , meat. | | <i>L. thalassina</i> ♂. |
| (c) | 1. Small grasshopper. | | 2. <i>E. hiarbas</i> and <i>C. metis</i> . |
| | 2. <i>Dielis 5-fasciata</i> and <i>Salix</i> , the other two wasps being quite likely refused through likeness to the <i>Dielis</i> . | | |

A good mimicry experiment, three homœochromatic groups being successfully tested.]

Exp. 193.—In the late afternoon, hungry, she refused, then tasted slightly, and again refused an *A. areca* ♀, and after it refused a large ♀ black and chestnut *A. esebria*, which, had it been spotted, would have been by no means unlike the *A. areca*; both had their upper surface fully displayed. On my now showing the under surface the *A. areca* was again refused, but the *A. esebria* tasted before rejection.

A little later I offered the *A. esebria* with upper surface displayed. It was this time tasted and rejected, and thereafter both it and an *A. cabira* (much like it, except for size) were persistently refused without tasting. A *Terias senegalensis* was eaten.

After a few grasshoppers the roller tasted and rejected, then refused, a *Terias regularis* and persistently refused a *Teracolus auxo*, a *Terias senegalensis*, and a *T. brigitta*, but ate a *Mycalesis campina*.

[Another experiment, illustrating well how a bird may be deceived or rendered suspicious by a likeness, while ready to test any new pattern. It is probable that

the *A. cabira* escaped trial through its resemblance to the *A. esebria* which had been tried and rejected, and the *Teracolus*, *Terias senegalensis*, and *T. brigitta* mainly through their likeness to *T. regularis*. *T. senegalensis* was preferred to the *Acraeas* tasted and *M. campina* to *Terias regularis*, and each seemed to indicate the bird's state of appetite when influenced by the resemblances.]

Exp. 194.—*March 4.* Twice seized the head and thorax of a huge Elaterid beetle (*Tetralobus* sp.) from in front, and each time the beetle "clicked" itself clean out of her bill. She then refused for a time to touch it again, but finally made a flank attack, seizing it across at the joint of the thorax and abdomen, and commenced to bang its head against the perch, but, after the first blow, the beetle, which had probably slipped back in its bill, released itself as before.

Exp. 195.—*March 4.* Very hungry indeed, accepted an *A. lobengula* and crushed it well, and would, I believe, have swallowed it had it not stuck across her bill. This gave more time for hesitation and she ended by throwing it away, afterwards refusing to touch either it, *Pap. echerioides* ♀, *A. johnstoni*, or *A. esebria* (buff hind-wing like this group), though doubtful over the latter, but she at once accepted, crushed, and ate *Amauris albiguttata*. After a small grasshopper she refused to again touch *A. albiguttata*, *A. lobengula*, *A. johnstoni*, *P. echerioides* ♀, and the *A. esebria*, but readily enough accepted and ate an *A. igola*. Of all the above the upper surface only was shown. The bird next tasted unhesitatingly and rejected, underside uppermost, a dull white (and black) *A. esebria*, and refused it and a white-marked *A. johnstoni* without tasting, as also a buff-patched *A. esebria* and a buff-patched *A. johnstoni*.

Later she tasted and rejected *Planema aganice* and refused both it and a large black and white ♀ *A. esebria*, both with upper surface shown, and went on once more to refuse the whole of the previous two series and the *P. aganice* (underside). She then ate several grasshoppers, a *Mycalesis campina*, and a few more grasshoppers, took with disinclination but threw away the next *M. campina*, then refused it, refused too *M. safitza* and a dull ♀ *Crenis boisduvali*, readily ate an *E. hiarbas*. These were all offered with upper surface shown. On my reoffering them with only the under surface showing the bird persistently refused to touch the *M. campina*, tasted rather hesitatingly and rejected the *M. safitza*, and readily took and ate the *Crenis*, then tasted and rejected the yellow-legged *Salix*.

[A mimicry experiment that is worth a little study with the insects before one. Thus while the two species of *Mycalesis* and the *Crenis* are sufficiently alike on their upper surface to render it intelligible that the bird might refuse the other two after rejecting one, their under surfaces are unlike in the degrees actually indicated by the bird's treatment of them when thus offered. The preferences shown were *A. igola* to *Amauris albiguttata*; *E. hiarbas* and *C. boisduvali* to *M. campina* and *M. safitza*.]

Exp. 196.—*March 5.* Very hungry. Refused persistently to touch either a large Elaterid (*Tetralobus* sp.), probably remembering its previous acrobatic feats, or a

larva of the large Saturniid, *Gynanisa ethra* (pale green with silver spikes, only about one-fifth grown), or an *A. caldarena*, refused, then hesitatingly tasted and threw away a *Planema aganice*, refused it, a large white-and-black ♀ *A. esebria*, and a *Pap. echerioides* ♀, all showing the *underside* only, accepted with reluctance, then tasted well and threw away a small Saturniid larva of the same species (perhaps one-fifth grown), eagerly ate a *Belenois severina* and, from the state of her hunger there evinced, would, I felt sure, have taken even a *Mylothris* had I had one to offer.

[Order :—

1. *B. severina*.
2. Larva of *Gynanisa ethra*, *P. aganice* ♀, *A. caldarena*, *Tetralobus* sp.

A further mimicry experiment, this time to test such resemblance as exists between the undersides of *Pl. aganice*, *A. esebria*, and *Pap. echerioides* ♀.]

Exp. 197.—*March 21.* Very hungry indeed. Accepted an *A. lobengula* and crushed it very thoroughly before rejecting it, almost disposed to eat it, a second time accepted and rejected it, then refused to touch it again and equally persistently refused a ♀ *Aterica galene* (upperside in each case), but ate (an indication of some hunger) a very large spiky-legged *Acridium* (*A. lineatum*), and showed the greatest eagerness for a *Charaxes brutus* I was carrying to a bulbul.

[A very striking suggestion of the probable value to *A. galene* of its resemblance to *A. lobengula*.]

Exp. 198.—*March 23.* Very hungry. Persistently and with shakes of the head refused to touch a *P. echerioides* ♀ with upper surface displayed, also refused to taste a *P. dardanus* ♀ f. *trophonius* either with wings open or closed, or a *Danaida chrysippus* offered in both positions. On my now reoffering the *P. trophonius* she showed a distinct inclination to try it, but decided not to, refused positively an *A. encedon* and a *Mimacrea marshalli*, and once more became interested in the *Papilio trophonius*, upper surface, but ended by again refusing it; refused positively to touch an *A. albimaculata* with light hind-wing patch, leant forward to take an *A. johnstoni* (which she should now be getting to know well), but thought better of it and withdrew—both these were offered with upper surface shown,—but at once seized it when offered with *closed* wings, crushed and swallowed it.

Refused to touch *A. caldarena* ♂, refused, then tasted and rejected red ♀ *A. igola*, but accepted and ate a *Callioratis bellatrix* and another *A. johnstoni* (underside), refused most emphatically and persistently without tasting *P. echerioides* ♀, upper-side, but at once seized, crushed, and readily ate a ♂ with closed wings. She then refused persistently to have anything to do with three Indian butterflies, *Parantica aglea*, Cram., ♀, *Papilio chaon*, Westw., and *Papilio memnon agenor*, Linn., each with an appropriate local body—actually those of *P. echerioides* ♂ and *P. lyæus* respectively,—but eagerly ate an actual *P. lyæus*.

[An interesting mimicry experiment, the absolute refusal of *P. trophonius* before the bird was visually reminded of the *Danaida's* exact appearance, and his inclination to take it afterwards being highly suggestive. That it still was not taken seems a

testimony to the deterrent value of even an imperfect likeness, and that no inclination to take *A. encedon* or *M. marshalli* was displayed illustrates the view that a still more perfect likeness may be still more effective. The treatment of *A. johnstoni* and *P. echerioides* ♀ respectively was equally interesting, and the bird was shown to be hungry enough for either.

The three Indian butterflies were offered to test previous knowledge, as *C. garrulus* visits India in its migrations. However, the result, though a refusal, can hardly be regarded as in any way conclusive.

Preferences:—1. *A. johnstoni*, *P. echerioides*, *Callioratis bellatrix*, and *Pap. lyæus*.
2. *A. albimaculata*, *D. chrysippus*, *A. caldarena* ♂, and red ♀ *A. igola*.]

CORACIAS GARRULUS. B.

Exp. 199.—April 2. Refused to touch a *Diestogyna iris* ♀ or a *D. chrysippus*, but at once tried to seize on a *D. chrysippus* f. *alcippus*. I withdrew it and once more offered the other two, which were as persistently refused as before. I then reoffered the *alcippus*, and this time allowed the roller to seize it, which she did readily; but on crushing it she threw it away, refused, then crushed and rejected an *A. johnstoni*, readily ate a *Terias brigitta*, and reached out readily enough for an *M. yulei*. It was old and dry, and was accordingly at once rejected. I had merely offered it to see whether it would be refused without tasting.

Half an hour later, no food meantime, she tasted and rejected the Indian Danaine, *Parantica aglea*, with a lively *D. chrysippus* body, refused then to touch either it or a *Nepheronia ceylanica*, showed some inclination to try *Hestia nama* but refrained, refused to touch *Tirumala septentrionis*, tried *Chittira fumata* with a *Danaida* body and rejected it, again refused persistently to have anything to do with the *Tirumala*, but hesitatingly once more tried the *Parantica* and again rejected it. I now gave a small feed of grasshoppers, then offered a *Terpsichrois mulciber*, which I had accidentally omitted before. It was refused without tasting.

In this experiment the roller went back on his refusal of *Parantica* the other day and showed a much more marked suspicion of *Tirumala*.

[The special testing invited by an unaccustomed colour-variation was illustrated at the commencement of the experiment, a form of *D. chrysippus* being thus specially tried when even a rather poor mimic of the commoner form was avoided. The Indian butterflies also gave rise to quite a good colour-experiment and the refusal of the *Terpsichrois*, unlike the others in coloration, struck me as conceivably due to previous experience.

T. brigitta and *M. yulei*, both well known to the bird, were preferred to *D. chrysippus* and *A. johnstoni* and, with the latter, fixed exactly her state of appetite. She was probably even hungrier after the interval, though less so when it struck me to offer the *Terpsichrois*.]

Exp. 200.—April 7. Hungry—early morning. I placed several coffee-bugs (*Antestia lineaticollis*) in cage. The roller descended, tried one or two and rejected them, then returned to her perch. From the forceps she refused one, then tasted

and rejected it with disgust, refused an *Epilachna hirta*, refused, then in turn tried and threw away, an *Amauris albimaculata*, an *Acræa caldarena*, and an *A. igola* ♂, but readily accepted, crushed, and ate an *Mylothris rueppelli*. [*M. rueppelli* preferred to each of the other insects.]

Exp. 201.—April 18. Very hungry. Tried and rejected a larva of *A. albimaculata*, refused, then tried and rejected *A. caldarena* and *A. esebria* ♀, accepted, crushed, and ate a *Rhodogastria bubo* (foam exhausted) and an *M. yulei*, tried with her bill and refused to take a large weevil (*Brachycerus apterus*) and a *Psammodes mashunus*, and refused to even taste a *Psammodes* sp. or a *Psammodes perfidus*, again refused *A. caldarena*, but took another *Rhodogastria*, and crushed it well before throwing it away.

I then gave her a feed of grasshoppers, after which she refused, then tried and rejected, a hive-bee, and refused to taste again either it, a *Podalirius vestitus*, or two flies mimicking Hymenoptera, ate a few more grasshoppers, tried and rejected a bee (*Xylocopa*), and refused to touch again either it or large flies with the same colouring, refused persistently with shakes of the head to taste a Lycoid Lygæid bug, accepted a Lycoid *Nupserha*, and crushed it very thoroughly before throwing it away—evidently it was not very highly disliked,—then refused to touch a *Myc. campina* or a *Papilio angolanus*, but readily ate a *Charaxes brutus natalensis*, wings and all.

[Preferences:—

- | | |
|------------------------|---|
| | 1. Grasshoppers and <i>Charaxes brutus</i> . |
| <i>M. campina</i> , | { 2. Lycoid <i>Nupserha</i> . |
| <i>P. angolanus</i> . | |
| Hive-bee. | { 3. <i>Rhodogastria bubo</i> . |
| <i>Pod. vestitus</i> . | |
| <i>Xylocopa</i> . | |
| | 4. <i>A. caldarena</i> , ♀ <i>A. esebria</i> , and (through hardness) <i>Psammodes mashunus</i> , <i>P. perfidus</i> , <i>Psammodes</i> sp., and <i>Brachycerus</i> . |

Also a mimicry experiment, Dipteron mimics of Hymenoptera being tested and two members of the Lycoid group. The Lycoid Lygæid, though not actually tasted in this experiment, is actually very low grade indeed, and the *Nupserha*, whose Lycoid coloration failed to save it from tasting, was shown to be, if anything, probably more acceptable than *M. campina* and *P. angolanus*.]

Exp. 202.—April 18 (continued). Later in the day (had had a feed meantime) refused, then barely crushed and dropped, a *Belenois mesentina*, readily ate a *Myc. campina* and a small piece of meat, refused to touch a second small piece of meat or a second *M. campina*, but readily ate after crushing each a *Glutophrissa saba* (ochlea-like), a *P. isokani* ♂, and a *Teracolus achine* ♀, refused to touch *M. campina*, but readily accepted and ate *Neptis agatha* and *Byblia goetzius*.

[Order:—

1. *N. agatha* and perhaps *B. goetzius*, *G. saba*, and perhaps *P. isokani* ♂ and *Teracolus achine* ♀.
2. *M. campina* and possibly the meat.
3. *B. mesentina*.]

Exp. 203.—*April 24.* Had had a good feed not long before, but had since brought up a large and a small pellet. Refused, then tried and rejected, *Brachycerus apterus*, then ate no less than six *Acridium lineatum*—an unusual feat, for the larger specimens are usually found somewhat unmanageable, but these were all fairly small, running roughly three to the ounce. She then ate a large number, weighing in all two-thirds of an ounce, of small grasshoppers of various species, finally refusing to take any more. But she accepted and, after running it through her bill with a somewhat uncertain air, finally swallowed without the smallest sign of dislike the contents, extracted in one piece, of the abdomen of the large *Brachycerus* she had previously rejected. She then refused with shakes of the head to touch *P. angolanus*, refused a *P. lyceus*, but, as I continued to offer it, finally accepted, crushed it, and played with it for some seconds, tossing it into the air and catching it again, then threw it away and refused to touch it again. She then refused to touch a small grey larval mantis, a light brown Locustid, a Tsamon-tree Locustid or a mantis. The first two and the last of these she had to my knowledge had before now in her food. She similarly refused a *Precis elgiva*, a *Rhop. pisistratus*, and an *Antanartia schæneia*, but accepted, crushed, and held a *Rhop. libeon*. She appeared too replete to swallow it and could not be induced to do so, though she each time made some show of activity, even by means of a fluttering *Charaxes vologeses* held in front of her bill. I left her, and returning five minutes later found her still holding *R. libeon*, which, however, she now relinquished in favour of the *C. vologeses*. She failed with this too, as also with a *Charaxes ethalion* ♂ and a *C. brutus*, relinquishing each in turn after crushing it and holding it for several minutes in her bill. No sign of dislike was shown for any of them, nor of regret for having eaten the *Brachycerus* contents. At the same time she had filled up unusually quickly after refusing grasshoppers.

[Order :—

1. Contents of *Brachycerus apterus*, probably about on a level with *R. libeon*, *C. vologeses*, *C. brutus*, and *C. ethalion*.

Probably *R. pisistratus*,
P. elgiva, *A. schæneia*,
 the two Mantises, the
 two Locustids, *P. angolanus* and *P. lyceus*.

2. *Acridium lineatum* and grasshoppers generally.
3. Uncrushed *B. apterus*.]

Exp. 204.—*April 27.* Refused without tasting, then tried and rejected, *Mylothris rueppelli*, readily accepted and ate a *Belenois mesentina* and several large grasshoppers, crushed and rejected a *B. mesentina*, readily ate a *Byblia ilithyia*, took two more grasshoppers, refused to accept a *Byblia goetzius* or the *B. mesentina*, but crushed and at once swallowed the Lycænid that mimics *Nyctemera* (the first ever captured at Chirinda itself). But, pushing down her crop-contents by means of an elongation of the neck followed by a visible contraction (this had happened as I offered the Lycænid too), she went on to eat not only the *B. goetzius* but the *B. mesentina*, though she refused, then crushed slightly and rejected, a *Terias senegalensis*.

Later. I had just placed in her cage a feed after a hungry spell, when it struck me to offer the pupa of *A. albimaculata*. She had already eaten the first grasshoppers, and she attacked and crushed well, then threw away, the pupa. As she at once continued her feed, it was useless to offer anything for comparison with the pupa, but it was evidently fairly strongly disliked.

[Order :—

Grasshoppers.	{	1. <i>Nyctemera</i> -like Lycænid.
	{	2. <i>B. ilithyia</i> .
		3. <i>B. mesentina</i> (<i>T. senegalensis</i> not better than it).
		4. <i>M. rueppelli</i> .

Amauris albimaculata pupa was probably placed low.]

Exp. 205.—April 30. Refused to touch or taste a driver-ant, *Dorylus* sp., with shakes of the head, but accepted, crushed, and ate an *A. terpsichore*.

Exp. 206.—May 2. Should have been very hungry before morning meal, which was in any case late. Refused, then barely tasted and threw away, an *Epilachna hirta*, refused, but quickly tasted slightly and rejected, a turnip sawfly larva (*Athalia* sp.), ate fairly readily five coffee-bugs (*Antestia lineaticollis*), refused, and on my continuing to hold it to her tried and rejected, *A. albimaculata*, refused *A. neobule* and *A. serena*, refused, then barely tasted and rejected, *A. serena*, tried and rejected *A. cabira*, but ate with hesitation another coffee-bug.

Considerably later, no food meantime, she refused another coffee-bug, and after it once more refused to touch a *Mylabris*, *Epilachna hirta*, the sawfly larva, *Amauris albimaculata*, *Acræa neobule*, *A. natalica*, *A. buxtoni*, *A. cabira*, again the coffee-bug, and a *M. rueppelli*, but very readily accepted and ate a *Belenois mesentina*.

[Order :—

1. *B. mesentina*.

<i>Mylabris</i> ,	{	2. <i>Antestia lineaticollis</i> .
<i>M. rueppelli</i> ,		3. The other earlier insects used.]
<i>A. natalica</i> .		

Exp. 207.—May 3. Crushed well and swallowed a swollen cattle-tick (*Rhipicephalus* sp.), tasted and rejected a black recurved ant (*Polyrhachis gagates*), a grey ant, an unswollen tick, a driver-ant (*Dorylus*), several fruit-flies (*Ceratitis*) held together in the points of the forceps, but evidently regarded two or three black aphides (of orange) as too insignificant to deserve attention, most persistently refused without tasting *Amauris albimaculata*, crushed slightly and rejected in turn *Acræa serena*, *M. agathina* ♀, and a *T. senegalensis*, but readily accepted and ate *B. mesentina*, again tried and rejected fruit-flies (*Ceratitis*), ate a fly of the species used for the "drivers" the other day, but looked exceedingly doubtful after it and shook her head. She refused to accept a second, but after some persuasion on my part tried it and threw it away, then readily ate a full-fed cattle-tick, and after a great deal of battering an *Enyaliopsis petersi*.

[*B. mesentina*, a full-fed cattle-tick, and probably *Enyaliopsis petersi* preferred to any of the others, including *T. senegalensis* and unfed cattle-tick of same species. The eating of fly was probably a mistake.]

Exp. 208.—*May 3.* Later, hungry before a meal, refused persistently to accept a *P. dardannus* ♀ f. *cenea*, upperside exposed.

[Doubtless a result of its excellent likeness to *Amauris lobengula*.]

Exp. 209.—*May 23.* Refused with a shake of the head a coffee-moth larva and continued to refuse it. This was not long after a feed, though not a very large one. The bird would quite likely have eaten a *Neptis* had it been offered.

Exp. 210.—*May 24.* Hungry before a meal. Readily accepted and ate two coffee-berry-moth larvæ, accepted, probably inadvertently, and at once threw away in great disgust an *A. lobengula*, refused to touch a white-banded ♀ *Acræa doubledayi* or an *A. esebria* ♂, but finally on my pressing it on her tasted and threw the last away, refused to touch an *Mylothris yulei*, readily accepted, crushed, and ate a ♀ *M. agathina*, and after it ate the *M. yulei* too, refused the *A. esebria*, but finally on my pressing it on her again tried and rejected it, readily ate a coffee-moth larva and a number of grasshoppers, etc. She then once more ate a coffee-moth larva, refused obstinately to touch *B. mesentina*, *T. senegalensis*, *Myc. campina*, *N. agatha*, or *B. ilithyia*, but readily accepted, crushed, and ate a *Leuc. thalassina* ♂ and with disinclination a coffee-moth larva. After a few more grasshoppers she repeated all her previous refusals, but readily ate an *Eurytela dryope*, crushed and flung away a *Myc. campina*, and, though accepting it with disinclination, at once swallowed after crushing it another coffee-moth larva. I had not the material wherewith to conclude the experiment, but it was already evident that the larva was not greatly disliked. This was perhaps to be expected in the case of an insect that spends a great deal of its time hidden away in or amongst berries.

[Order:—

- | | |
|---|--|
| (a) 1. ♀ <i>M. agathina</i> , coffee-moth larva, grasshoppers. | (b) 1. <i>L. thalassina</i> ♂, <i>E. dryope</i> , grasshoppers, moth-larva probably not higher. |
| 2. <i>M. yulei</i> , ♀ <i>A. doubledayi</i> , ♂ <i>A. esebria</i> , and <i>A. lobengula</i> . | 2. <i>B. mesentina</i> , <i>T. senegalensis</i> , <i>M. campina</i> , <i>N. agatha</i> , and <i>B. ilithyia</i> .] |

Exp. 211.—*June 4.* An experiment by lamplight. Accepted and ate three pieces of meat, threw away the rest, and refused obstinately to accept any more (freshly dead leg of lamb), readily accepted and ate a *Bel. mesentina*, crushed and rejected a *Terias brigitta*, crushed very thoroughly and ended by rejecting a *Xylocopa africana*, merely took in the tip of her bill, crushed slightly, and dropped another *Xylocopa* and *X. senior* ♂, and readily ate another *Bel. mesentina*.

Shortly afterwards she crushed and rejected *Xylocopa senior* ♂, refused both it and the other two, and readily ate a *Bel. mesentina*.

These refusals and acceptance she repeated twice again with intervals between.

Next time she ate a *B. mesentina*, crushed and rejected *Xylocopa* sp., and refused both it and the other two species, then readily ate both a *Bel. mesentina* and the *Terias senegalensis*.

A little later again she crushed very thoroughly indeed and ended by swallowing a *Xylocopa africana*, refused a second, also ♂ *Xylocopa senior* and the third species, a *Mylothris yulei*, and a piece of meat, accepted a *Terias brigitta*, but, after a great deal of crushing and an evident inclination to eat it, rejected it and very readily accepted, crushed slightly, and swallowed a *Belenois mesentina*, afterwards once more refusing the bees.

[Order :—

1. *B. mesentina*.
2. Perhaps, on manner, *Terias brigitta* and *senegalensis* and *Xylocopa africana*.
3. The other *Xylocopas*, *M. yulei*, and lamb.]

Exp. 212.—*June 5.* Hungry, just before morning meal, readily ate a ♂ *Acraea serena*, crushed and rejected in turn an *A. asema* and an *A. caldarena*, readily ate a ♀ *A. serena* and two pieces of meat, crushed slightly and rejected *Xylocopa africana*, refused to touch either it or *Xylocopa* sp. and *X. senior* ♂, crushed and rejected a ♂ *A. serena*, and readily ate a *Mylothris yulei*.

I kept reoffering the three bees at intervals, ♂ *X. senior* usually first. Sometimes they were refused without tasting, sometimes merely taken in the point of the bill, crushed slightly, and dropped; none eaten or even accorded anything like a serious crushing.

On the last occasion the roller crushed slightly and rejected an *A. serena* and, in turn, the three bees, refused these, again crushed slightly and rejected the *A. serena*, but accepted, crushed, and readily ate a ♂ *M. agathina* and a piece of meat.

[Order :—

- | | |
|-------------------|---|
| | 1. ♂ <i>M. agathina</i> and, perhaps, lamb. |
| <i>Xylocopa</i> { | 2. <i>A. tersichore</i> . |
| spp. 3. { | 3. <i>A. caldarena</i> and <i>A. asema</i> .] |

Exp. 213.—*June 6.*—Refused to touch *A. caldarena*, crushed slightly and dropped *A. serena*, refused, then accepted, crushed slightly, and rejected two moth-larvæ eaten by the natives, refused to accept an *A. esebria*, an *A. serena*, or a *Mylothris yulei*, but very eagerly seized on, crushed, and swallowed a *Belenois mesentina*, evidently much preferred to any of the others.

Exp. 214.—*June 7.* Probably quite hungry; before early morning feed. Readily accepted, crushed, and swallowed four Termites (two small soldiers and two small workers).

[Returning in the evening, after an absence, I found that the hornbills had pulled out several trays and that the roller and *P. layardi* B had in consequence escaped, while the kingfisher had found his way into the roller's cage. A careful search, continued throughout the next morning, failed to discover the roller; her wings were in excellent condition and she had possibly flown away. But the bulbul returned on the 8th with a request for re-admission.]

EXPERIMENTS ON *CORACIAS GARRULUS*. C.

Exp. 215.—*March 7, 1911.* A just-captured roller (*C. garrulus*) was brought to me this morning. By the afternoon he was already so much at ease as to readily accept insects from the forceps. I gave him a *Rhabdotis* larva and a number of grasshoppers, after which he refused to touch an *A. caldarena*, a *D. chrysippus*, an *A. esebria* or an *M. rueppelli*, but readily accepted and ate a *Padraona zeno*, refused a *Terias senegalensis*, a *Lyc. lemnos*, a *Myc. campina*, and a *Crenis boisduvali*, these last two offered with upper surface displayed, but accepted readily and ate a *Leuceronia thalassina* ♂, refused a ♂ *Lycus* sp., again refused the *Mylothris* and the *Terias*, also a *Precis natalensis* ♂ f., readily took, crushed, and ate an *A. schæneia* and after it to my surprise swallowed down the *Myc. campina*, but seemed annoyed and refused to touch another or the *Crenis* re-offered, even with the underside up, refused a second *Leuceronia thalassina* and again the *Lycus*, accepted a little doubtfully but on crushing it readily ate an *Andronymus neander*, refused a *P. demodocus* and a *P. lyæus*, and on my persisting in offering them took each from the forceps and without tasting them dropped them on the ground, but readily ate a *Cylogramma latona*, then took and dropped a *Rhabdotis* larva and a small grasshopper, tried and rejected *Charaxes candiope* and *Sphingomorpha chlorea*. The *Charaxes* and the *S. chlorea* were each simply snatched from the forceps, crushed and dropped and a grasshopper was similarly treated; but, judging from the preceding portion of the experiment, the bird must in any case have been nearly replete.

[Order :—

- | | | |
|--|---|---|
| <i>A. schæneia</i> . | { | 1. <i>C. latona</i> and <i>A. neander</i> . |
| | | 2. <i>L. thalassina</i> ♂. |
| <i>Lycus</i> sp. ♂,
<i>C. boisduvali</i> ,
<i>Precis natalensis</i> ♂ f.
(or whatever it was
taken for). | { | 3. <i>A. caldarena</i> , <i>A. esebria</i> , <i>D. chrysippus</i> , <i>M. rueppelli</i> ,
<i>T. senegalensis</i> , <i>Lycænesthes lemnos</i> , <i>M. campina</i> (and,
if not taken for <i>M. campina</i> , <i>C. boisduvali</i>). |

C. latona also over *P. demodocus* and *P. lyæus* and quite as high as the grasshopper, *C. candiope*, *S. chlorea*, and the *Rhabdotis* larva.

P. zeno over at any rate the first four species in Grade 3 above.

But the great point of the experiment was that a bird captured that very day and without previous experience of them in captivity should have given proof of its experiences in the wild state by refusing to touch a *Danaine*, two species of *Acraea*, a *Mylothris*, a *Terias*, a *Lycænesthes*, a *Mycæsthes*, and a *Lycus*, and, when nearly replete, a *P. demodocus* and a *P. lyæus*—all of them more or less disliked by my long-captive roller,—while readily accepting and eating species that my long-captive roller would also under those conditions of appetite have readily eaten. The refusal of the *Precis natalensis* was probably due to its *Acraea*-like appearance, and the first refusal of the *Crenis* seemed due, possibly, to its likeness to *M. campina*, but its subsequent refusal when the underside also was shown may have indicated that, if known, it was itself then unacceptable.]

Exp. 216.—*March 8.* After a few grasshoppers, would have nothing to do with an *A. caldarena* or a *Terias brigitta*, and on my persisting in offering them snatched each from the forceps and without attempting to taste or crush it dashed it on the ground. But he at once accepted and ate a *Sph. chlorea*. The next four offerings were four days old and dry, but were offered to test his previous knowledge of insects of their respective colour-patterns. He refused to touch a *Redoa melanocraspis*, at once accepted a *Neptis goochi*, but after crushing it threw it away, presumably because dry, persistently refused without tasting a "*Terias Teracolus*," but readily enough accepted a *Myc. campina*, and treated it as he had done the *Neptis*. He then refused to touch an *Aulacophora vinula*, tasted and dropped a grasshopper No. 47, then picked it up again, crushed it and threw it away, ate a grasshopper 1051, at once accepted but, on crushing it, threw away a *Mylabris oculata*, readily accepted and ate a *P. demodocus*, an *L. thalassina* ♂ and a *C. brutus*, refused persistently to touch a *Lyc. lemnos*, but readily accepted and ate a ♀ *Crenis boisduvali* offered underside uppermost. He now refused to accept grasshopper 47, readily ate grasshopper 1061, refused 47, tried and rejected 1051, readily ate the common grasshopper with red wings and black and white marks under thorax, readily ate No. 86, refused 1051, readily accepted and ate 1061 and 19, then barely tasted and emphatically refused 19, 1061, and the white-chequered one, refused emphatically and persistently without trial *A. albimaculata* (outspread upper surface) and *D. chrysippus* (underside), but greedily accepted and swallowed the very large moth, *Nyctipao macrops*, and showed the greatest eagerness for a *Ch. brutus*, which, however, I required for another experiment and withdrew. But I shortly afterwards offered him a *Ch. candiope*, which he at once swallowed, as usual, wings and all.

It surprised me in the above experiment that the roller was apparently less sure of his beetles and grasshoppers than of his butterflies.

One-and-a-half hours later, no food meantime, tried and rejected a house-fly (*M. domestica*) and a hive-bee, tried and rejected a ♂ grasshopper 1051, dropped, then ate a ♀ and readily accepted and ate a smallish *Acridium lineatum*. No hesitation had been shown in tasting the house-fly and very little, if any, over the hive-bee. It had now clouded over heavily, and it is possible that if he knew the insects' placings well already it was too dark in the verandah to allow of certain recognition.

[Order :—

A.

1. *N. goochi*, *M. campina*, probably *S. chlorea*.
2. *A. caldarena*, *T. brigitta* and *Redoa melanocraspis*.

The *Teracolus* was probably taken for a *Terias*.

B.

- | | | | | |
|--|---|--|---|--|
| <i>C. brutus</i> ,
<i>C. boisduvali</i> ,
<i>P. demodocus</i> ,
<i>L. thalassina</i> ♂. | } | <i>A. lineatum</i> ,
grasshopper
86. | { | 1. <i>Nyct. macrops</i> & probably <i>C. brutus</i> & <i>C. candiope</i> .
2. Grasshoppers 1061, White-chequer, and 19. |
| <i>A. albimaculata</i>
<i>D. chrysippus</i> . | } | 3.
4. | { | 1051.
47, <i>Aulacophora vinula</i> , <i>M. oculata</i> ,
<i>L. lemnos</i> , <i>Musca domestica</i> , and hive-bee. |

Again numerous low-grade Lepidoptera (and one low-grade beetle) were refused without tasting, an indication of previous experience in the wild state. They were *D. chrysippus*, *A. albimaculata*, *A. caldarena*, *T. brigitta*, the *Terias*-like *Teracolus*, *L. lemnos*, *R. melanocraspis*, and *Aulacophora vinula*, and the refusal of the *Teracolus* was a probable indication of the value of mimicry relatively even to a just-captured bird.

Exp. 217.—*March 9.* Refused emphatically and persistently *A. caldarena*, a dull ♀ with outspread wings, and *Terias senegalensis*, tried and rejected a *Deudorix*, refused emphatically without tasting *A. albimaculata*, but readily accepted and ate *E. hiarbas*, most persistently refused without tasting a blue-black beetle-larva (*Catamerus*), a Lycoid moth, and again the *Terias*, crushed and readily ate *B. mesentina*, persistently refused without tasting the *Terias* and a *D. chrysippus*, showed some slight inclination to accept a ♀ *Hypolimnas misippus* (no bar) but did not do so, persistently refused without tasting *Azanus moriqua* and *Castalius calice*, inspected closely and ate *Catochrysops dolorosa*, persistently refused without tasting *Castalius sybaris*, inspected and readily accepted and ate *Atella phalantha*, refused without tasting then tried and rejected a rather dry *Phycenura*, both surfaces shown, tried and rejected the *Deudorix*-like *Lycænesthes*, readily accepted and ate *Antanartia schœneia* and a yellow ♀ *Catopsilia florella*, most persistently refused without tasting the *Terias*, *A. lobengula*, and a small Lycid (*Brachycerus*), ate an *Ypthima*, most persistently refused without tasting a large weevil, but at last pressed slightly and desisted, refused similarly without tasting an Ichneumon, refused without tasting and then with disinclination tried and rejected *B. mesentina* and *Atella*, persistently refused without tasting *Terias*, readily accepted and ate *N. agatha*, *Ypthima impura*, *Eurytela hiarbas*, and a *Hæmatopota* (?), refused without tasting then tried and rejected a house-fly, readily accepted and ate *E. hiarbas*, refused without tasting then tried and rejected a very large *Tryxalis*, decidedly refused without tasting *Tryxalis turrita*, but readily ate a grasshopper 19, most persistently refused without tasting the *Belenois* and the *Atella* and once more the large *Tryxalis*, readily accepted and ate various grasshoppers including *Catantops sulphureus* and now, after at first refusing it, a *T. turrita*, persistently refused without tasting it the large *Tryxalis*, but readily accepted and ate grasshopper No. 1053.

In the afternoon, hungry, he most persistently refused without tasting a *Terias*, but readily accepted and ate a *B. mesentina* and an *A. phalantha*.

[Order:—

- | | | |
|---|---|--|
| <i>C. dolorosa</i> , <i>Ypthima</i> ,
<i>A. schœneia</i> , & probably
yellow <i>C. florella</i> . | { | 1. <i>N. agatha</i> , <i>E. hiarbas</i> , grasshoppers 19 and 1053, and perhaps <i>Ypthima</i> sp., <i>Hæmatopota</i> sp., and <i>Catantops sulphureus</i> .
2. <i>A. phalantha</i> and <i>B. mesentina</i> . |
| <i>Lycænesthes</i> sp., <i>Azanus moriqua</i> , <i>Castalius calice</i> and <i>sybaris</i> , <i>D. chrysippus</i> , <i>Phycenura</i> , <i>A. lobengula</i> , small Lycid, large <i>Brachycerus</i> and Ichneumon. | { | 3. <i>T. senegalensis</i> , <i>Lycænesthes</i> sp., <i>A. albimaculata</i> , dull ♀ <i>A. caldarena</i> , blue-black Tenebrionid larva, and, if known on its own merits, which is unlikely, the Lycoid moth. |

Additionally, *Ypthima* was placed above the *Lycaenesthes*, *A. moriqua*, *C. calice* and *sybaris*, *Physcenura*, *D. chrysippus*, *A. lobengula*, and the small Lycid; *A. schæneia* and perhaps yellow *C. florella* above these except possibly the first two; *C. dolorosa* and *A. phalantha* above at any rate *A. moriqua*, *C. calice* and *sybaris*, and *D. chrysippus*; *E. hiarbas* above *Musca domestica*; and grasshopper 19, grasshopper 1053, and probably *Catantops sulphureus* above *M. domestica*, *Tryxalis* sp., and *T. turrita*.

N.B. (1) Inclination to try unbarred *H. misippus* (*inaria*).

(2) Close inspection before acceptance of *C. dolorosa* at a time when certain other small Lycenids were unacceptable, including a *Lycaenesthes* with an underside not unlike *C. dolorosa*'s in general effect.

(3) The further refusals without tasting, indicating probable previous acquaintance, of dull ♀ *A. caldarena*, *A. albimaculata*, *A. lobengula*, *D. chrysippus*, *A. moriqua*, *Castalius calice* and *sybaris*, *T. senegalensis*, the blue-black Tenebrionid larva, the too-hard *Brachycerus*, the Ichneumon, *Tryxalis turrita*, and *Tryxalis* sp., and two members (model and mimic) of the Lycoid group—namely, *Lycus* sp. and a Lycoid moth.]

Exp. 218.—*March 20.* Refused emphatically and persistently an *A. lobengula*, took without enthusiasm, crushed and threw away a *Terias brigitta*, ate a *Belenois severina*, most persistently refused without tasting *M. agathina*, *A. neobule*, *A. esebria* (♂), *A. johnstoni*, and *A. lobengula*, readily accepted and ate *Henotesia perspicua*, picked up and ate some grasshoppers lying in cage, most persistently refused without tasting *P. echerioides* ♂ with underside shown, but at once accepted it reoffered with upperside uppermost, crushed it well and threw it away, refusing to touch it again. I then offered a *C. brutus*, with upperside similarly displayed and it was refused, but, on my showing the underside, at once accepted, crushed, and swallowed.

The bird appeared to be suffering some discomfort after swallowing the *Charaxes*. He has diarrhoea to-day and is evidently not very well. He then most persistently refused without tasting *Papilio echerioides*, upperside, *E. hiarbas*, *Byblia goetzius*, and *A. phalantha*, accepted an *A. schæneia*, but dropped it after crushing it, refused without tasting, then took with disinclination and dropped a *P. lyceus*, most persistently refused without tasting *P. hippocoon*, upper surface, accepted it with under surface up and forewings well back behind the hindwings, crushed and swallowed it, then brought it up again and rejected it, again very positively refused without tasting *A. phalantha*, *E. hiarbas* (underside), *P. hippocoon* and the *Byblia*, accepted and dropped a *P. elgiva*, picked it up again, crushed and dropped it, persistently refused without tasting *P. demodocus*, accepted a *C. candiope*, showing some eagerness as it was approached to him, but could not bring himself to eat it either.

Later in the day most persistently refused without tasting *Amauris albimaculata*, *A. johnstoni*, *A. esebria*, *A. igola* ♂ and black-and-white ♀, *A. caldarena*, *P. aganice* ♂, *M. rueppelli*, *Pinacopteryx isokani* ♂, *T. brigitta* and *B. severina*, all offered with closed wings; readily accepted and ate *E. hiarbas*, most persistently refused without tasting *B. severina*, *A. phalantha*, *P. hippocoon* with spread wings, *B. goetzius*, *P. natalensis* ⊕ f., *Teracolus* sp. (upperside shown), *Lachnocnema bibulus*, *T. brigitta*, *P. isokani* ♂, and *M. rueppelli*, readily accepted and ate

Neptis agatha, again persistently refused without tasting all the above, but readily accepted and ate *Neptis swynnertoni*, again persistently refused without tasting all, descended and ate three or four grasshoppers, most persistently refused without tasting *E. hiarbas*, ate an *A. schæneia*, most persistently refused without tasting *P. dardanus* ♂ and *P. demodocus*, refused but then tried and rejected *P. hippocoon* (underside), persistently refused without tasting *P. echerioides* ♂ (upperside), refused without tasting, then crushed and dropped *P. angolanus*, refused without tasting, then took and dropped *P. demodocus*, and after the usual persuasion took and this time ate a *P. lyceus*, again persistently refused without tasting the rest, also *A. schæneia*, both white and yellow *C. florella*, *Platylesches picanini*, and *Padr. zeno*, but accepted a *C. candiope*, afterwards refusing a *P. elgiva*. Again ruffled and sick-looking.

[SUMMARY :—

1st experiment :—

A.

1. *H. perspicua*, *C. brutus*, grasshoppers, *B. severina* above *T. brigitta*, but not tested against *A. neobule*, &c.
2. *T. brigitta*, on manner above } *M. agathina*, *A. neobule*, *A. esebria* ♂,
3. *A. lobengula*. } *A. johnstoni*.

B.

1. *C. candiope* on manner above
2. *P. hippocoon*,
3. *A. schæneia*, & *P. lyceus*. } *P. elgiva*.
4. *P. echerioides* ♂, *E. hiarbas*, *B. goetzius*, *A. phalantha*, *M. agathina*, *T. brigitta*, *A. esebria* ♂, *A. johnstoni*, *A. neobule*, *A. lobengula*.

The details of the mimicry experiment are interesting: the bird probably at first took *P. echerioides* ♂ with upper surface shown for *C. brutus* and, discovering his mistake, took *C. brutus*, till shown its under surface, for the *Papilio*; and in finally refusing the latter probably recognised it for what it was.

2nd experiment :—

Grasshoppers,

N. agatha,

N. swynnertoni.

1. *C. candiope*.
2. *A. schæneia*, *P. lyceus*,
3. *E. hiarbas* (not tested against spp. after "also").
4. *B. severina*, *T. brigitta*, *P. isokani* ♂, *M. rueppelli*, *P. aganice* ♂, *A. caldarena*, *A. igola* ♂ & white ♀, *A. esebria*, *A. johnstoni*, *A. albimaculata*; also *A. phalantha*, *P. hippocoon* with open wings (perhaps taken for *A. dominicanus*), *B. goetzius*, *P. natalensis* ⊕ f. (perhaps taken for an *Acræa*), *Teracolus*, *L. bibulus*.

P. dardanus ♂ &
P. hippocoon ♀,
P. demodocus ♂,
P. echerioides,
P. angolanus.

C. florella white
& yellow ♀ ♀,
P. piccanini,
P. zeno.

The greater readiness to try *P. hippocoon* with closed wings than with open was interesting, occurring as it did in both experiments, in view of the strong upper-surface likeness to *A. dominicanus* and far less good under-surface likeness. The upper-surface refusal of ♂ *P. echerioides* was probably the result of so recent an experience of it.

In both experiments many insects were refused obstinately without tasting that the bird has not tasted since capture, probably in most cases showing previous knowledge, since the bird readily accepted certain other insects. These were in the first experiment *A. lobengula*, *A. neobule*, *A. esebria* ♂, *A. johnstoni*, *N. agathina*, *P. echerioides* ♂ underside, *B. goetzius*, *P. hippocoon* upper surface (taken probably for *A. dominicanus*); in the second experiment *A. albimaculata*, *P. hippocoon* upper side (probably regarded as *A. dominicanus*), *A. johnstoni*, *A. esebria*, *A. igola* ♂ and white ♀, *A. caldarena*, *P. aganice* ♂, *M. rueppelli*, *P. isokani* ♂, *Teracolus*, *P. dardanus* ♂, *P. angolanus*, *Lachnocnema bibulus*, *B. goetzius*, and *P. natalensis* wet f. (probably taken for a large *Acræa*).

The extent to which the bird's preferences as shown to-day should be discounted owing to his being out of sorts and suffering obvious discomfort on approaching repletion can best be judged by a comparison of them with those of other days.]

Exp. 219.—*March 21.* Very hungry, snatched an *A. lobengula* from the forceps, but at once threw it down in disgust, refusing thereafter to touch either it or *A. galene*, uppersides shown. But he showed the greatest eagerness for a *Charaxes* that I was carrying to the bulbs.

[An excellent illustration of the value of mimicry.]

Exp. 220.—*March 23.* Not very hungry. Most persistently refused without tasting *P. echerioides* ♀ with wings closed and *P. trophonius* both open and closed; he leant forward as though to take the butterfly in the latter position, but withdrew again; he most persistently refused without tasting *Danaida chrysippus*, each surface in turn, and once more *trophonius* upper surface, *A. encedon*, *Mimacrea marshalli*, *A. albimaculata*, and *A. johnstoni*, all with wings open. I then offered the last with closed wings. It was at first ignored, but on my continuing to hold it to the bird was taken, tasted, and rejected. The bird then most persistently refused without tasting *A. caldarena* and *A. igola*, refused but on my pressing it on him tasted perfunctorily and rejected *Callioratis bellatrix*, refused, then in the same way tasted and rejected *B. mesentina* and, having treated *P. echerioides* ♂ (spread) in the same way, refused to touch a *C. brutus* with outspread wings and looking, therefore, like *P. echerioides* ♂. But on my closing them and showing the underside he seized it with the greatest eagerness, crushed the thorax, and swallowed the butterfly wings and all.

He half an hour later refused persistently with shakes of the head to touch the Indian *Danaine*, *Parantica aglea* (its wings on an *echerioides* body), but after at first refusing then seemed inclined to attack two Indian *Papilios*—*P. chaon* and *P. memnon agenor*. Whether he would actually have done so had I not withdrawn them I do not know. Were there sufficient evidence to indicate that this bird had ever been to India I would prefer to accept his evidence, as a more recent migrant, than that of B with regard to these *Papilios*.

[*C. brutus* preferred to the other recognized African butterflies and, if the roller knows them (as his refusal of *Parantica* might indicate), *P. chaon* and *P. agenor* to *P. aglaea*. Some of the refusals in African butterflies were probably the result of their resemblance to others, and a comparison of the bird's treatment of *P. trophonius* before and after a visual reminder of *D. chrysippus* may usefully be compared with that of my long-caged roller (C), as showing that a comparatively newly-captured bird may be even more impressed by an imperfect likeness than even a long-captive one—as against my remarks in the Introduction. The probable advantage to *C. brutus* of its excellent upperside likeness to *P. echerioides* was very prettily illustrated.

Butterflies refused without tasting that have not yet been tasted since the bird's capture were: *D. chrysippus* (and its mimics *P. trophonius*, *A. encedon*, and *M. marshalli*), *A. albimaculata* (and its mimic *A. johnstoni*—tried, however, when its under surface was displayed); but *A. lobengula* was tasted yesterday, *A. caldarena*, *A. igola*, *Callioratis bellatrix*, and *Parantica aglaea* (Oriental).]

Exp. 221.—*March 25.* Refused to touch a black and red *Acraea esebria*, an *A. johnstoni*, an *A. igola*, an *A. areca* ♂, a *M. yulei*, or a *Terias brigitta*, first refused, then crushed and rejected *M. campina*, *Neptis agatha*, and *N. gooichi*, readily ate after crushing them a *P. hippocoon* and an *A. schæneia*, refused, then tried and rejected, an *E. hiarbas*, accepted, crushed, and ate an *H. perspicua*, absolutely refused to taste a very dark ♂ *M. campina*, accepted, tried, and rejected a far paler ♀ (more like *Henotesia perspicua* in general colour), accepted with disinclination, crushed, and rejected a *P. lyceus*, a *P. dardanus* ♂, and an *A. schæneia*, took more readily, I thought, a *Crenis natalensis* and a *P. elgiva*, crushed and threw them back as though to swallow them, but after further crushing rejected each and readily ate a *C. candiope*.

[Order:—

<i>P. hippocoon</i> ,	1. <i>C. candiope</i> .	These, except <i>A. schæneia</i> , purely in manner or on degree of inclination ap- parently shown.
<i>H. perspicua</i> .	2. <i>Crenis natalensis</i> and <i>P. elgiva</i> .	
	3. <i>P. lyceus</i> , <i>P. dardanus</i> ♂, and <i>A. schæneia</i> .	
	4. <i>E. hiarbas</i> , <i>N. agatha</i> , <i>N. gooichi</i> , <i>M. campina</i> .	
	5. <i>A. esebria</i> (red and black ♀), <i>A. johnstoni</i> , <i>A. areca</i> ♂, <i>M. yulei</i> , <i>T. brigitta</i> .	

The incident of the dark and the pale individuals of *M. campina* would seem to illustrate what might occur to the individuals of any species that approached in coloration a less unpleasant known species.

Butterflies refused without tasting that have not been tasted since the bird's capture were: *A. esebria* (chestnut and black), *A. johnstoni*, *A. igola*, *A. areca* ♂, and *Mylothris yulei*.]

Exp. 222.—*March 27.* Refused in turn, then crushed and rejected *Mylothris yulei*, *T. brigitta*, *B. severina*, and *Myc. campina*, readily accepted and, after crushing each, ate an *Atella phalantha* and a *Ph. isokani* ♂ (which I brought up

quickly to minimize risk of refusal for a *Mylothris*); tried and rejected *M. campina*, ate readily *N. agatha*, *E. hiarbas*, and *H. perspicua*.

Later. Refused persistently without tasting *T. brigitta*, ate readily *M. campina*, refused without tasting then tried and rejected *T. brigitta*, ate readily *B. severina*.

Later, hungrier, ate readily *T. brigitta*, *M. yulei*, and *A. esebria* ♂, refused most persistently without tasting *D. chrysippus* and *A. lobengula*, accepted, crushed well, and threw away *A. caldarena*. He then ate several grasshoppers, &c., refused, then tried and rejected *T. brigitta* and *M. campina*; more grasshoppers, then tried and rejected *A. phalantha* and *A. hiarbas*, showed an inclination to swallow *A. schæneia* and *P. tugela*, but ended by throwing each away. Refused without tasting, then tried and rejected *P. lyæus* and *P. dardanus* ♂, tried and rejected *P. tugela*, ate readily *C. brutus* and *C. candiope*.

[Order:—

- | | | |
|-----------------------|---|---|
| <i>N. agatha</i> , | { | 1. <i>C. brutus</i> and perhaps <i>C. candiope</i> . |
| <i>P. isokani</i> ♂, | | 2. <i>A. schæneia</i> and <i>P. tugela</i> , on manner above |
| <i>H. perspicua</i> . | | 3. <i>E. hiarbas</i> & <i>A. phalantha</i> , probably <i>P. lyæus</i> & <i>P. dardanus</i> ♂. |
| | | 4. <i>M. campina</i> , <i>B. severina</i> . |
| | | 5. <i>T. brigitta</i> , <i>A. caldarena</i> , prob. not above <i>T. brigitta</i> , <i>M. yulei</i> , or <i>A. esebria</i> ♂. |
| | | 6. <i>D. chrysippus</i> and <i>A. lobengula</i> , for which less inclination was shown than for <i>A. caldarena</i> and the other species in grade 5. |

D. chrysippus, always hitherto refused without tasting, was so refused again to-day.]

Exp. 223.—*March 27.* Towards evening. Refused, then tried and rejected *M. campina*, accepted readily, crushed and ate without hesitation *H. perspicua*, accepted *Papilio echerioides*, but on crushing it threw it away with very evident dislike. Refused without tasting, then tried and rejected *M. campina*, ate readily *Henotesia perspicua*, tried and rejected *E. hiarbas*, *P. lyæus*, and *Tagiades flesus*, apparently regarded white *C. florella* with suspicion, refused, then took it in the point of his bill, crushed it slightly, and dropped it. He also rejected an *A. schæneia*, but he readily accepted, crushed, and swallowed a *Precis clelia*, accepted and crushed a *P. dardanus* ♂, then flung it away, crushed and rejected an *H. perspicua* and *Tagiades flesus*, refused, then rejected a *C. florella* and an *E. hiarbas*, but very readily ate a *P. tugela*. It took me four or five minutes to hunt up another *A. schæneia*; having got it, I offered *C. florella* and *P. lyæus*. The first he refused, the second, after a refusal, crushed and rejected, but he readily ate the *A. schæneia*, then refused to touch *P. dardanus* ♂, *E. hiarbas*, and again *P. lyæus*.

After a short interval he once again crushed and rejected an *E. hiarbas*, accepted and ate a *P. lyæus*, refused, then crushed and rejected, again with marked dislike, a ♂ *P. echerioides*; also, once more, the *E. hiarbas*; accepted and ate a *P. dardanus* ♂ and refused *E. hiarbas* and the *C. florella*. I then adopted my common trick of bringing the latter up quickly and unexpectedly to his bill. He at once seized it, looked a little doubtful when he saw what it was, but after crushing it well, swallowed it with no sign of dislike. He then tasted and rejected *Neptis swynnertoni*, and with almost a show of eagerness seized on a *Leuceronia argia* ♂

Exp. 224.—*March* 28. Refused even to taste *A. caldarena*, *A. johnstoni*, *T. brigitta*, but readily accepted and ate an *M. campina*, again refused, then barely tasted and rejected the *Terias*, but ate an *Argiolaus lalos* and three grasshoppers. He then refused persistently to touch a *T. senegalensis*, refused, then crushed and rejected an *M. campina*, but crushed and readily enough swallowed a *Byblia goetzius*, accepted a *Neptis goochi* with some disinclination, crushed, and dropped it, crushed and readily ate a *Tagiades flesus* and refused to touch again either the *N. goochi* or a second *B. goetzius*. After one more grasshopper he refused a ♂ *L. argia*, then tried and rejected it, accepted readily, crushed, and ate a ♂ *P. dardanus*, refused, then tried and rejected *L. argia*, and after it a *C. florella*. On my removing their wings he crushed both, rejected the *Leuceronia*, but readily ate the *C. florella*, again rejecting the *Leuceronia*. He then ate a *P. lyæus*.

After an interval he crushed and rejected *N. goochi*, crushed and readily ate an *E. hiarbas*, refused a *Neptis agatha*, but crushed and this time ate the *Leuceronia argia* ♂.

Considerably later (he had had a good feed of grasshoppers in the meantime) he refused persistently to touch a *Mycalesis campina* or a *Eurytela hiarbas*. Finally, with an air of "All right—give it me and be hanged to you!" he snatched the latter from the forceps and swallowed it, but refused to touch another, though offered again with coaxing several times during the next twenty minutes. On the last occasion he refused the *Eurytela hiarbas*, opened his mouth and brought up a large pellet, then (immediately) readily accepted not only the *Eurytela hiarbas* but a *Mycalesis campina*. Refused, then tried and rejected *Belenois mesentina*, ate readily another *Mycalesis*, again refused the *Belenois* but changing his mind ate it and crushed and rejected *Mylothris rueppelli* and *Terias brigitta*.

Twenty minutes after the ejection of the pellet he readily accepted, crushed, and ate not only *Mylothris rueppelli* but *Acraea esebria* and *Acraea caldarena*, tasted and rejected ♀ (white-barred) *Acraea doubledayi* and a second ♂ *Acraea caldarena*, crushed and quickly rejected *Mylabris tristigma*, crushed far more thoroughly, seeming inclined to eat it, a *M. oculata*, then threw it away, tasted and at once hastily flung away an *Epilachna*, refused to accept an *Acraea caldarena* ♂, tasted and rejected a red ♀ of *Acraea igola*, crushed an *Acraea johnstoni* well and half swallowed it but brought it up and rejected it, tasted and rejected an *Acraea esebria* ♂, crushed and readily ate *Mylothris yulei*, refused the *Acraea esebria*, refused, then tasted and rejected a *Nyctemera leuconoë*.

After three grasshoppers he refused, then tasted and rejected in turn *Mylothris yulei*, *Terias brigitta*, and *Terias senegalensis*.

After an interval he refused *Acraea caldarena*, but crushed and ate *Nyctemera leuconoë*, refused persistently *Acraea caldarena*, crushed *Acraea johnstoni* well before throwing it away, crushed and swallowed *Papilio echerioides* ♂, brought it up into his bill again, tasted it further and swallowed it finally, refused *Acraea johnstoni*, snatched at a *Mylothris yulei* through the bars (I reserved it for further use), ate a small grasshopper, and crushed and rejected a *Terias brigitta*.

After a further short interval he accepted and ate the *Terias* and snatched again at the *Mylothris*, breaking off and swallowing the head with a small part of the thorax, crushed and rejected *Acraea natalica* and *Acraea caldarena*, then refused

each without tasting, readily ate an *Acræa johnstoni*, refused then tried and rejected *Acræa caldarena*, crushed and ate a red ♀ *A. igola* and three grasshoppers.

He then crushed and rejected *Terias brigitta*, accepted and ate the remains of the *Mylothris yulei*, again rejected the *Terias brigitta*, accepted, crushed, and ate a *Terias senegalensis*, refused two or three times, then crushed and rejected *Terias regularis*.

Later (he had had a smallish feed and some two hours then without food) he crushed and rejected an *Amauris albimaculata*, crushed and swallowed an *Amauris lobengula*, and crushed and rejected an *Amauris albimaculata*, *Amauris lobengula*, *Acræa caldarena*, and *Terias brigitta*. He was now looking much annoyed with upraised frontal feathers and had, I believe, made a mistake. He once more refused the *Terias*, also a *Terias regularis*, then tried and rejected the latter, but readily ate a *Belenois severina* and six or seven grasshoppers.

He then accepted and ate a *Mycalesis campina*, refused a *Belenois severina*, ate another *Mycalesis*, and again refused the *Belenois*.

["*N. goochi* was evidently not liked better than the *Byblia*; nor to judge both from the bird's manner and from his refusal of the *Byblia* only one butterfly later, very much worse."

Probable order:—

- | | | |
|------------------------|---|--|
| <i>T. flesus</i> , | { | 1. <i>P. dardanus</i> ♂, <i>P. lyæus</i> , <i>C. florella</i> . |
| <i>E. hiarbas</i> , | { | 2. <i>L. argia</i> ♂. |
| <i>B. goetzius</i> . | | 3. <i>N. goochi</i> with or just above |
| | | 4. <i>M. campina</i> . |
| | | 5. <i>B. severina</i> and <i>mesentina</i> . |
| <i>Nyctemera</i> { | | 6. <i>M. yulei</i> . |
| <i>leuconoë</i> . { | | 7. <i>P. echerioides</i> ♂. |
| | | 8. <i>A. johnstoni</i> . |
| <i>A. esebria</i> . | { | 9. Red ♀ <i>A. igola</i> , <i>M. oculata</i> per- |
| | | haps here. |
| | | 10. <i>A. caldarena</i> , <i>A. natalica</i> , <i>M. tristigma</i> perhaps hereabouts. |
| <i>A. doubledayi</i> . | { | 11. <i>Epilachna</i> 171 possibly, on manner, below even <i>M. tristigma</i> . |
- T. senegalensis* hereabouts.
T. brigitta about here.
T. regularis not above *M. yulei* and *T. senegalensis*.
- N. agatha* below *L. argia*, *T. flesus*, and *E. hiarbas*.
A. lalos above *A. johnstoni* and *T. brigitta*.
M. rueppelli probably not below *A. caldarena* or above *B. mesentina*.]

Exp. 225.—*March* 31. Refused, then crushed and rejected *Acræa caldarena* ♂. Ate readily *Acræa johnstoni*.

After a medium-sized grasshopper, refused persistently *Acræa johnstoni*, *Mylothris yulei*, and *Terias brigitta*, but ate readily *Belenois mesentina* and *Mycalesis campina*.

Later refused without tasting, then tried and rejected *Acræa esebria*, *Mylothris yulei*, and *Terias brigitta*. Ate readily *Mycalesis campina*.

[Order:—

- | | |
|--|---|
| 1. <i>B. mesentina</i> , <i>M. campina</i> . | |
| 2. <i>A. johnstoni</i> . | { <i>M. yulei</i> , <i>T. brigitta</i> . |
| 3. <i>A. caldarena</i> ♂. | { <i>A. esebria</i> (latter tried only against <i>Mycalesis</i>).] |

Exp. 226.—*April 1.* Refused most emphatically and persistently *Terias regularis*, refused, then barely tasted and again refused *Belenois severina* and *Mycalesis campina*, tried *well* and rejected *Pseudacraea lucretia* and *Eurytela hiarbas*, ate readily *A. phalantha*, ate readily *Eurytela dryope* and *Henotesia perspicua*, tried and rejected *Eurytela hiarbas*, ate readily *Eurytela dryope*.

I was here interrupted. A little later the bird accepted and ate a *Eurytela hiarbas*, a *Mycalesis campina*, and a *Belenois mesentina*, but refused most emphatically and persistently *Terias regularis*.

- [1. *A. phalantha*, *E. dryope*, and perhaps *H. perspicua*.
2. *P. lucretia* and *E. hiarbas*, more seriously considered than
3. *M. campina* and *B. severina*; these less decidedly refused than
4. *Terias regularis*, which later was shown to be also probably, at any rate, not better than *B. mesentina*.]

Exp. 227.—*April 2.* *Experiments with Indian butterflies.*—Only moderately hungry. Refused to touch a *Danaïda chrysippus*, rubbed somewhat, like its successor, a *Diestogyna* ♀, a much-rubbed specimen, or a *D. c. alcippus*, accepted, crushed, and rejected an *Acraea johnstoni*.

Half-an-hour later, noticeably hungrier, but I did not ascertain the exact degree; he refused an Indian Danaine, *Tirumala septentrionis*, with its own body (relaxed), refused, then pecked disapprovingly at a *Parantica aglaea* furnished with the body of a lively *Danaïda chrysippus* (he often pecks without grasping or strikes with the side of his bill, both in token of disapproval), but I withdrew it for further experiment and cannot be certain that he might not have tried it eventually. Refused to touch *Papilio polyctor ganesa* (upperside shown; metallic blue and green), but after refusing the first showed an inclination to accept *Troides darsius*, *Papilio protenor* (both underside), and, after them, *Papilio ganesa* again. The last two were each attached in turn to the body of a *Papilio lycaeus*; refused most emphatically to have anything to do with *Parantica aglaea*, *Tirumala septentrionis*, or their mimic *Nepheronia ceylanica*, but showed some slight interest in *Papilio memnon agenor*, ending, however, by refusing it, and again refused to touch *Tirumala septentrionis* or *Parantica aglaea*, but attacked *Papilio protenor*, which, however, I withdrew.

I then gave the bird a feed of grasshoppers, after which, finding I had forgotten to offer the Indian Danaine, *Terpsichrois mulciber*, I did so. The roller persistently refused to touch it, refused *Mycalesis campina*, crushed and rejected *Pseudacraea lucretia*, refused, then crushed and rejected *Eurytela hiarbas*. Tried and rejected *Eurytela dryope*, ate a *Papilio lycaeus*, though without enthusiasm, refused to taste again *Eurytela dryope* or *Eurytela hiarbas*, crushed and rejected *Antanartia schœneia*, refused without tasting a *Henotesia perspicua*, a *Papilio dardanus* ♂; a *Papilio lycaeus*, and, persistently, a *Papilio demodocus*, but readily accepted, crushed, and ate a *Melanitis leda* and a *Rhopalocampta forestan*, afterwards crushing very thoroughly and throwing away the *A. schœneia* re-offered; but he readily ate, after crushing it, a *Precis artaxia* ☉ f., refused again to taste *Papilio demodocus* or *Papilio lycaeus*, but ate without apparent dislike a *Tagiades fesus* and a *Rhopalocampta libeon*, afterwards refusing *Papilio demodocus*, *Papilio lycaeus*, *Antanartia schœneia*, and *Eurytela hiarbas* and *dryope*.

A little later he again refused *Eurytela hiarbas*, readily ate *A. schæneia*, refused, then crushed and rejected *Papilio demodocus*, refused most persistently *Papilio lyæus*, accepted and ate, but this time with disinclination, an *A. schæneia*, refused to taste *Papilio demodocus*, *Papilio lyæus*, or another *A. schæneia*, but accepted, crushed, and ate a *Precis antilope* ♂ f.

A few minutes later he again refused *Eurytela hiarbas*, accepted, crushed, and threw away the *Papilio demodocus*, refused *Papilio lyæus* and *Papilio dardanus* ♂, refused, with shakes of the head, but finally tasted hesitatingly and, having done so, crushed and swallowed a *Charaxes zoolina*, regarded with apparent suspicion, and three or four times accepted, crushed, and dropped *Precis natalensis* wet f.

After a further and longer interval he refused positively and persistently to touch *Mycalesis campina*, *Neptis goochi*, *Eurytela hiarbas*, *Papilio demodocus* ♀, *Papilio dardanus* ♂, *Papilio lyæus* ♂, *Hypolimnias misippus* ♂, a *Charaxes brutus*, which I offered repeatedly, rubbed round his bill, let flap in front of him and, in short, did everything I knew to tempt him with, and several of the more palatable grasshoppers. He was looking straight in front of him with the thoughtful and abstracted air of a bird about to bring up a pellet.

And, sure enough, he brought it up, immediately afterwards seizing, crushing, and swallowing a grasshopper. I was interrupted here.

Sixteen minutes later he persistently refused *Acraea johnstoni*, refused for a moment, then changing his mind, accepted and ate a *Mycalesis campina*, then accepted and crushed very thoroughly, but finally threw away and refused to receive again a *Belenois severina*.

I now gave each of the other birds their noon-day feed of grasshoppers, &c., and the roller was disappointed and angry at getting none. He sulked for a time, refusing to accept from me any butterflies whatsoever, even *Charaxes brutus* or *candiope*, which he probably prefers to any grasshoppers, then took to battering against the bars and trying generally to get out to them. Once he refused obstinately *Mycalesis campina* and *Neptis goochi*, but ate readily *Eurytela hiarbas*, barely tasted and refused the next, refused persistently *Neptis goochi*, ate readily *Herpennia eriphia*, but then ate a *Mycalesis campina*, too. When I finally gave him the grasshoppers he ate them eagerly, even including several species that ordinarily he would not have looked at beside a *Papilio lyæus*, to say nothing of a *Charaxes*. Later he accepted, crushed well, and half swallowed a *Eurytela hiarbas*, but thinking better of it brought it up again, crushed it again, and rejected it. He refused both upperside and underside, then crushed and rejected *Hypolimnias misippus* ♂ and *Papilio demodocus*, refused, then barely tasted and rejected *Papilio dardanus* ♂ accepted and ate a *Tagiades fesus* and a *Henotesia perspicua*, and again refused *Hypolimnias misippus*, *Eurytela hiarbas*, *Papilio demodocus*, and *Papilio dardanus* ♂. A delay of less than five minutes occurred here while I hunted up one or two butterflies; he then crushed well and swallowed *Precis natalensis* (wet) and ♂ *Hypolimnias misippus*, but refused to touch the *Papilio demodocus* or the *Papilio dardanus*.

Soon afterwards he refused to touch *Mycalesis campina* or *Neptis agatha*, tasted and at once rejected *Eurytela hiarbas*, refused *Atella phalantha*, accepted *Papilio*

demodocus, crushed it thoroughly and was disposed to swallow it, but changing his mind ended by rejecting it, crushed and at once rejected *Papilio lyceus*, refused persistently to touch an *Everes cissus* (underside shown) or a *Papilio angolanus*, the latter with many shakes of the head, but accepted, crushed, and ate a *Precis antilope* ☉, refused, then crushed, and threw away an *A. scheneia*, but readily accepted and ate a *Charaxes brutus*.

There was little doubt in my mind that he had liked *Papilio demodocus* at least as well as *Papilio lyceus*.

The *Pseudacraea lucretia* was now dead and beginning to dry, so was not used in the latter part of the experiment.

[1. The points of interest about the Oriental butterflies were the refusal of the Danaines and the refusal of their mimic, *Nepheronia ceylanica*. It is, of course, quite likely that, even if the bird had not been to India he would, in travelling south through Africa, have come across *Tirumala petiverana*, and so have refused Indian butterflies with much the same colour-pattern; and his indecision over the Indian Papilioninae lends colour to this explanation, though it is opposed by his obstinate refusal of the very different-looking *Terpsichrois*. His refusal of *alcippus*, uncommon at Chirinda, was also probably based on experiences further north, if not in the fore-wing likeness to typical *D. chrysippus*. The latter butterfly, persistently refused ever since the bird's capture, was again refused, and its protective influence on one of its mimics, *Diestogyna*, illustrated, though he had to remind himself of *A. johnstoni* by again tasting it. Further interesting points were his suspicion of *Acræa*-like *P. natalensis* wet f., the pellet incident and its results—less marked than last time,—and the special eagerness shown for grasshoppers (and especially, doubtless, for a square meal) after only butterflies, mostly of unsuitable species, had been offered for some time.

2. Order of preference :—

<i>H. eriphia</i> , Grasshoppers, including 1051 and 45.	1. <i>P. antilope</i> ☉ f., <i>P. artaxia</i> ☉ f., <i>M. leda</i> , and perhaps <i>R. forestan</i> and <i>libeon</i> .	} <i>C. brutus</i> , <i>C. zoolina</i> .
	2. <i>A. scheneia</i> , <i>H. perspicua</i> .	
<i>E. cissus</i> , <i>P. angolanus</i> , <i>P. dardanus</i> ♂	3. <i>P. demodocus</i> , <i>P. lyceus</i> , ♂ <i>H. misippus</i> , and <i>P. natalensis</i> ⊕, also hereabouts, the latter probably higher.	} <i>A.</i> <i>phalantha</i> .
	4. <i>E. hiarbas</i> 4.	
	5. <i>M. campina</i> and } <i>N. agatha</i> , <i>B. mesentina</i> . } <i>N. goochi</i> .	
	6. <i>A. johnstoni</i> .	
		} <i>P. lucretia</i> <i>E. dryope</i> .

Exp. 228.—April 3. Readily ate a *Belenois mesentina*, refused to taste a *Terias senegalensis*, but accepted, crushed, and swallowed a *Mylothris rueppelli*, refused, then tasted and rejected a ♂ *Papilio echerioides* and refused a *Terias brigitta* and an *Acræa johnstoni*. After a grasshopper or two he refused a *Belenois*, accepted and ate with disinclination a *Mycalesis campina*, and accepted and ate with distinctly greater readiness a *Papilio angolanus*.

A little later he accepted and ate a *Mycalesis campina* and a large ♀ Saturniid moth with undeveloped wings, which I had found half drowned in a puddle and now gave to "fill up," refused, then tried with disinclination and rejected the next *Mycalesis campina*, but readily ate, after crushing each, an *Eurytela hiarbas*, a *Byblia goetzius*, a *Phrissura isokani* ♂, and a *Papilio angolanus*, a fair-sized grasshopper and another *Byblia*, four or five small grasshoppers, then refused, afterwards rejecting, a *Mycalesis campina*, but crushed and ate a *Neptis agatha*. After a few more small grasshoppers he refused to take either a *Mycalesis campina* or a *Neptis agatha*, but accepted a dry *Papilio angolanus*. It was an old specimen that I took from my collection, having no more fresh ones, in order to ascertain whether the species would now be refused without tasting; it was, of course, rejected. The roller next refused for a moment, then, after looking closely at it, accepted and ate a *Henotesia perspicua*, and accepted a dry *Papilio demodocus*, but on attempting to crush it threw it away, refused to taste an *Everes cissus*, accepted, crushed, and swallowed a *Rhopalocampta libeon*, refused, then accepted, crushed well, and ended by throwing away an *A. schæneia*, showed eagerness for a *Charaxes candiope*, which, however, I reserved, and with equal eagerness accepted and ate a *Cyiligramma latona*.

[Order:—

Prob. <i>P. angolanus</i> , <i>H. perspicua</i> and <i>P. demodocus</i> .	$\left\{ \begin{array}{l} 1. \text{ } C. \text{ candiope, } C. \text{ latona, with} \\ \text{greater eagerness than} \\ 2. \text{ } R. \text{ libeon, } A. \text{ schæneia.} \end{array} \right.$	$\left\{ \begin{array}{l} P. \text{ angolanus,} \\ \text{Grasshoppers,} \\ E. \text{ hiarbas and perhaps} \\ 3. \text{ } B. \text{ goetzius and } P. \text{ isokani } \sigma. \end{array} \right.$
<i>M. rueppelli</i> above <i>T. senegalensis</i> .	$\left\{ \begin{array}{l} 3. \text{ } N. \text{ agatha. 3.} \\ 4. \text{ } M. \text{ campina.} \\ 5. \text{ } B. \text{ mesentina at any rate} \\ \text{not below} \\ 6. \text{ } T. \text{ senegalensis, } T. \text{ brigitta, } A. \\ \text{johnstoni, \& } P. \text{ echerioides } \sigma. \end{array} \right.$	$\left. \begin{array}{l} \\ \\ \\ \\ \end{array} \right\} \text{Everes cissus.}]$

Conclusions from Experiments on Captive Rollers.

Many interesting conclusions and suggestions appear to arise from the above experiments. I will postpone the discussion of most of them until I come to publish my far more numerous and equally interesting experiments on very many other species of captive insectivorous birds. I will refer briefly to only one result here. It is that of the fine grading. It would appear that relatively few species of prey are eaten by a given individual enemy to repletion-point. Relatively to enemies *generally*—even individuals of the same species with their slightly-differing tastes—the number of absolute "Grade 1" species is yet further reduced. There are thus probably comparatively few species that do not at some time require to be distinguished by certain enemies from species acceptable nearer to repletion-point than themselves. Where their own parent-form was higher-grade than themselves they will, in order to gain any real advantage from their added nauseousness, have had to be distinguished from that parent-form. Where the present nauseousness has arisen by many steps the oft-repeated necessity for differentiation from successive parent-forms might, theoretically, have in

some cases cumulatively brought about, or contributed to, a very high degree of distinctiveness. This view was suggested to me in July, 1911, by my actual experimental results up to that date—in other words, by a consideration of the two lists which I append, and others like them. That on roller B is reinforced, so far as some of the lower grades go, by the unanimous verdict of animals on which I tested *Acræinæ* more thoroughly than on that roller. I give the tests as I originally worked them out, taking them from my letter of Feb. 16th, 1912, to Mr. Marshall, which he has kindly lent to me. I have worked out the results of each experiment far more exhaustively since and with a better knowledge of at any rate one complicating factor. The work of bringing these results together into one list like the one appended is not quite complete at the moment of my leaving England. I will add it later if I am not in time to replace the present list by it. It will, I believe, entail a few slight alterations in the first four grades. Otherwise (and in the main in those grades) the present list is approximately correct.

PREFERENCES OF *CORACIAS GARRULUS*. B.

↑ = not lower, possibly higher.

↓ = „ higher, „ lower.

1. *Charaxes* spp. (quite 12 spp. tried, including *neanthes* and *ethalion*). } *Euralia* (*mima* and *wahlbergi*) and
2. *Precis* spp. 10, *Orenis* spp. 2, *C. cloanthe*, } *Atella*, first impression; *E. neo-*
R. libeon, *P. cardui*, *H. dædalus*, *M.* } *phron*, *A. galene*, *Salamis* spp. 3,
leda, *Lachnoptera ayresi*(?), *Pyr.* pupa. } *C. pillana*, *Arrugia basuta*.
3. *C. florella*, *P. hippocoon*, *antheus*, and *policenes*, poss. }
ophidicephalus (? ↓). } *G. hottentota* (? ↑) and
4. *H. hippomene*, *H. perspicua*, *Hesperia* spp. (? ↑↓), *R.* } *T. flesus* hereabouts.
forestan and *pisistratus*.
5. *P. lyceus* and, if anything, slightly less liked, *P. demodocus*.
6. *P. dardanus* ♂ and *Euxanthe wakefieldi*.
7. *L. argia*. *Herpania eriphia* apparently hereabouts.
8. *L. thalassina*, *P. angolanus*, prob. *P. leonidas*, and, later placings, *E. wahlbergi* and *misippus*.
9. *E. dryope*, *P. echerioides*.
10. *E. hiarbas*, *P. natalensis* (wet), and *Atella*, latest placings, hereabouts. } *Cyrestis*
11. *N. agatha*, *N. swynnertoni*, *R. forestan* with *Amauris* smell. } *camillus*.
12. *N. saclava*, *P. lucretia* and *trimeni*; also, somewhat variably in 11, 12, and 13, }
Byblia spp., *Teracolus* spp., *Phrissina isokani*, and *C. saba* (latter poss. ↑).
13. *N. goochi* and, apparently, *Alaena*, *Teriomima*, *Physcenura*, and *P. peucetia* and }
tropicalis.
14. *M. campina*, *Ypthima* nr. *impura*, *Cycl. metis*. *M. safitza* prob. ↑.
15. *Belenois* spp. 4. *Azanus* spp. (and poss. *T. plinius*) here or even, possibly, }
lower.

16. *Terias* spp. 3. (*P. angolanus* fell as low as this, but the bird, reassured by a big series, restored it gradually but permanently to 8.)
17. *M. rueppelli*.
18. *M. agathina*.
19. *M. yulei*.
20. *M. leuconoë*. } *D. chrysippus* (on strength of mere taste).
21. *A. johnstoni*. }
22. *A. esebria*.
23. *A. buxtoni*, *A. igola*.
24. *A. asema* and *L. alcesta*.
25. *A. caldarena* and *A. doubledayi* ♂.
26. *A. doubledayi* ♀; prob. *A. natalica*.
27. *A. areca*, *A. lobengula*, and *albimaculata*.
28. *A. dominicanus*. } By some birds transposed.
29. *D. chrysippus*. }
30. Prob. certain beetles, Lepidopterous larvæ, &c., but I have yet to go into this more fully.
31. Prob. *Tetranychus* sp. (?).
32. *Brachycerus* &c. inedible to roller, and certain others through hardness.

PREFERENCES OF *CORACIAS GARRULUS*. C.

(As ascertained by a series of experiments commencing immediately after it was captured.)

1. *Charaxes* spp. }
2. *Precis* spp., *M. leda*. } *Cylogramma latona*,
3. *C. florella*. } *Rhopalocampta* spp., *T. flesus*. } *A. neanthes*.
4. *H. hippomene*, *H. perspicua*.
5. *P. lyæus*. }
6. *P. demodocus* and *dardanus* ♂ & ♀. } *P. natalensis* (wet) and *H. misippus*.
7. *E. dryope*, *A. phalantha*. }
8. *Leuceronia* spp., *E. hiarbas*. } *P. angolanus*.
9. *N. agatha* & *swynnertoni*, *P. lucretia* (↑?). } *N. goochi*.
10. *B. goetzius*, *A. phalantha*, *P. isokani*. }
11. *Myc. campina*. *L. bibulus* (? ↓ on own merits).
12. *Belenois* spp. and *M. rueppelli*.
13. *M. yulei*, *T. senegalensis*, *L. lennos*, *Azanus* (? ↓), *C. sybaris* and *calice* (? ↓).
14. *T. brigitta* (*regularis* not higher than *senegalensis*).
15. *A. johnstoni*, *N. leuconoë*, *P. echerioides* ♂.
16. *A. esebria*, *A. igola*.
17. *A. caldarena*, *A. natalica*.
18. *D. chrysippus* and *A. lobengula*.

NOTE (1912).—I think that the only essential difference between B and C's preferences, so far as ascertained, is the transposition of *Terias* and *Mylothris*, *M. rueppelli* being even placed as high as *Belenois* by C. The latter also places

P. echerioides very low, and in this is borne out by other birds; at the same time it is highly suggestive that the drongo, which at first placed not only *P. echerioides* but other *Papilioninae* in the neighbourhood of *A. caldarena*, should have promoted them, after fuller experience, to about the places they occupy in Roller B's list—*P. echerioides* actually considerably higher. This, in conjunction with that roller's treatment of *P. angolanus* (v. *Terias* in B's list) and the fact that the kingfisher kept the latter butterfly *permanently* in the neighbourhood of *Mylothris*, leads me to suppose that it is not a matter of much difference in preferences, but that the taste of some of these Papilios must be reminiscent of that of some highly distrusted insects—perhaps *Danaida*.

C drew a far harder line than B between Grades 1 and 2. B very frequently placed Grade 2 butterflies, and even those of Grades 3 and 4, in Grade 1.

Notes on the Bionomics, Embryology, and Anatomy of Certain Hymenoptera Parasitica, especially of *Microgaster connexus* (Nees). By J. BRONTÉ GATENBY, B.A., B.Sc., Senior Demy, Magdalen College, Oxford; Senior Assistant in Zoology, University College, London. (Communicated by E. S. GOODRICH, F.R.S., Sec.L.S.)

(PLATES 24-26, and 15 Text-figures.)

[Read 21st February, 1918.]

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Introduction to Section on *Microgaster connexus* (Nees).

IN a previous communication (11) I reviewed our knowledge of the polyembryony in parasitic Hymenoptera. In the polyembryonic species the host larva contains from fifty to one hundred or more parasitic larvæ derived

from one or more eggs laid by the host, which give rise each by a process of fission to the large number of larvæ found in the host's hæmocæl. In this paper I am describing the anatomy of the larva of a Braconid parasite. The polyembryonic species so far known are all Chalcids or Proctotrypids, none is a Braconid. The Aphidæ and Coccidæ are parasitized by a large number of species of Braconidæ of which the genus *Aphidius* is well known.

Other genera of Braconids which parasitize the caterpillars of many moths and butterflies are *Microgaster* and *Apanteles*. By far the greatest number of Hymenopterous parasites on the larvæ of common moths and butterflies, such as *Porthesia similis* and *Pieris brassicæ*, belong to the Microgasteridæ, though among the parasites of moth larvæ and pupæ are many Chalcids, Ichneumonids, and Tachinidæ (Diptera).

In this paper I have added some notes on certain observations I have made on an *Aphidius* of *Aphis pomi*, the reddish-brown aphid of the apple-leaf.

In several entomophagous internal parasites the larvæ are peculiarly modified for their *modus vivendi*, but I believe that the Microgasteridæ are among the most highly specialized, and the form with a large respiratory bulb has never before been properly examined. The peculiar larvæ of some Proctotrypidæ discovered by Ganin (15) have within recent times been re-examined by P. Marchal (19), but, though they are very bizarre in shape, I think that the tail vesicle of the Microgasteridæ is the most remarkable.

My thanks are due to Prof. Poulton and his assistants for some help and for the loan of specimens of Aphid parasites.

Bionomical Note and Previous Work.

The Hymenoptera have among their number forms whose remarkable habits and instincts have filled us with admiration. Though the instincts of the Hymenoptera Parasitica have rarely turned to a colonial life, they have been directed almost wholly to the hunting and capture of prey, and to the solution of many difficulties in oviposition, which might have been thought insurmountable. The reason why very little is known about the bionomics of Braconids, Chalcids, and Proctotrypids, is that they are almost all very minute creatures, and therefore very difficult to study successfully. Moreover, the Braconids especially are fairly shy insects, and it is often difficult successfully to handle them in captivity. The method in which these entomophagous parasites hunt their prey, the clever manner in which they contrive to deposit their eggs inside the body of their victim, and the curious individuality of method of procedure in different species, are alike very remarkable.

Porthesia similis is commonly called the "gold-tail" moth; the eggs are laid late in the year and the larvæ hibernate. In spring they come to life

and go on feeding till full-grown. If these spring larvæ are opened up they are often found to contain a number of parasitic larvæ which lie in the hæmocœl. Their number varies from fifteen to sixty. If numbers of the caterpillars be kept in a box and fed on their food-plant, it will be found that some of them give rise to the cocoons drawn in Pl. 24. fig. 5, at C.

It is rare for any caterpillars to get as far as the spinning operation, for the parasites inside their bodies choose this moment to bore their way outside the body of their host and to begin preparations for pupation themselves. In the closely allied genus *Apanteles* (*glomeratus*), a parasite on the "cabbage-white" *Pieris brassicæ*, I have watched this process. Towards the end of their larval life the parasitized caterpillars become "sleepy," and can easily be distinguished from their fellows because of their behaviour. I received a "sleepy" pierine caterpillar at ten o'clock one morning; up to two o'clock in the afternoon this caterpillar remained quiescent. Soon it began to squirm and move about in a characteristic manner. Clinging on by means of its hindmost prolegs, it slowly bent its body backwards and forwards in the form of an arc; gradually this movement became less violent, and from the sides of its body were seen appearing numerous small white points (text-fig. 4). These were the heads of the parasitic *Apanteles* larvæ, which latter had grown at the expense of the caterpillar. The host insect, clinging firmly to the branch, seemed soon incapable of anything but the smallest undulating movement of its body. By the time an hour had passed the parasites were mostly outside the body of their unfortunate victim. The latter, when prodded with a pin, was found incapable of much movement and would soon have died. The subsequent spinning of the cocoon by each parasitic *Apanteles* larva was not watched by me, as the caterpillar was killed with the parasites adhering to its body, as in text-fig. 5 at *x*. Goureau (6) remarks that a caterpillar of *Noctua oleracea* had nourished sixty *Microgaster* larvæ, and after being pierced by sixty holes to allow the exit of these larvæ, it still lived over a week, but it was incapable of walking and only made the smallest movements to show that it still lived*. According to Goureau (6, p. 360) the parasitic larvæ escape from the body of their host by making holes on each side of the line along which lie the stigmata. I found no such regularity, though most of the parasites did bore out through the sides of the caterpillar (text-fig. 5, *x*).

After the larvæ of *Microgaster connexus* have made their way out of the body of their host, the caterpillar of *Porthesia similis*, they spin their cocoons quite near the shrunk skin of their victim, as in Pl. 24. fig. 5. In other forms (as in the *Microgaster* sp. described by Marshall (2)), the cocoons stick separately over the body of the host. Such objects as the caterpillar skin and cocoons of its parasites are common to all those who have bred caterpillars. The cocoon of *Microgaster connexus* (Pl. 24. fig. 1) is of white or dirty white silk and is very strong and tears like rough parchment;

* See Entomol. Month. Mag. vol. v. p. 19.

that of *Apanteles glomeratus*, parasite of Pierines, is a beautiful yellow colour.

When the parasites have spun their cocoons, if winter is near they hibernate generally as larvæ inside their silken cells. If groups of cocoons taken after the time of emergence of the adult parasites be examined carefully, it will be noticed in the case of some cocoons that the parasitic fly has emerged from the cocoon by means of a beautifully even lid, which adheres on one side to the body of the cocoon to form a hinge (Pl. 24. fig. 1, at X). This is the manner in which the *Microgaster* individuals emerge; in the case of other cocoons no such hinged lid is to be found; instead there is found an ugly uneven hole at one side of the end of the cocoon (Pl. 25. fig. 9, X): this is the manner in which hyperparasites and hyper-hyperparasites emerge from the *Microgaster* cocoons.

It should at once be pointed out that not only *Microgaster*, but hyperparasites on *Microgaster* are attacked by other Hymenoptera, Ichneumonidæ, and Chalcididæ. The naked, unprotected mass of cocoons, as in Pl. 24. fig. 5, forms an attractive prey to other parasites who only need to bore through the silken wall to deposit an egg near the body of the *Microgaster* larva or pupa, or if the *Microgaster* has already been hyperparasitized, near the body of the hyperparasitic larva or pupa.

Having regard to the recent review (11) on the parasitic polyembryonic Hymenoptera, which also mainly pay their attentions to moth larvæ, it might be thought that the Microgasteridæ are polyembryonic. This opinion would certainly be strengthened when it is remembered that parasitized caterpillars of *Philampelus* produce as many as four hundred *Microgaster* individuals (2). Nevertheless it seems a fact that these Braconids are not polyembryonic; several observers agree that *Apanteles* and *Microgaster* do not lay their eggs singly (or a few) inside the egg of their host, as do the polyembryonic forms.

From the description of the Italian entomologist Martelli (3), I give the following account of the manner in which *Apanteles glomeratus* parasitizes the larvæ of *Pieris brassicæ*. The caterpillars are about three millimetres in length when they are attacked by the *Apanteles* (Seurat (12)). The *Apanteles* is an active, rather shy insect, about the same size as *Microgaster connexus* (5 mm.); it beats among the leaves of the cabbage till it finds a group of larvæ about the right size. Martelli picturesquely describes the agitation of the *Apanteles* as it sights its prey. It now stealthily marches forward little by little, rapidly vibrating its antennæ. The latter movement is very common among Hymenopterous insects (others as well). In many other parasitic forms the sight of the prey causes an excited vibratory movement of the antennæ—the senses become tense, and the little insect stiffens itself up for the not undangerous and extremely delicate task before it. The task of the *Apanteles* is as follows:—it has got to lay from sixteen to thirty

eggs inside the body of a very bristly caterpillar, at least its own size, and often bigger. According to Martelli the *Apanteles* quite often disturbs its prospective victim. The latter makes violent movements, signifying that it feels that "there is something afoot"; the parasite then draws back and waits till the caterpillar's agitation passes off; the parasite then moves up again, and if it is successful it approaches quite near, folds its antennæ back over the dorsal region of its abdomen, curves the latter little by little between its legs, after having raised itself on them. When the extremity of its body gently touches the lateral side of the victim's body, it suddenly darts its ovipositor into the latter and then clings on to the squirming caterpillar. The latter turns and twists, vainly trying to throw off its tormentor; the *Apanteles* hangs on, suspended in the air by its front and middle pair of legs. For ten minutes the parasite clings on, and during this time it lays in the hæmocœl of the *Pieris* larva from sixteen to thirty eggs. It then leaves go, and flies off. The elongate *Apanteles* eggs give rise by monembryony to the same number of larvæ as there were eggs. No account has ever been given of any stages of their development. The larvæ of *Apanteles* and *Microgaster* are much alike, and several observers have given more or less valuable descriptions of them.

Ratzeberg (14) has given a very short description of a *Microgaster* larva in his work on the "Forest Ichneumonidæ." He mentions the presence of tracheal tubes, but does not give any detailed attention to the anatomy of the larva. Seurat (12), in a paper on the structure of the entomophagous hymenopterous parasites, has given a short description of *Apanteles glomeratus* and *Microplitis seurati* (Marsh.). Seurat describes the larva as being formed of thirteen segments plus the head. The last segment consists of an enormous vesicle. There are no tracheal tubes in Seurat's figure, and as the skin is very thin this observer thinks that at this time (when the larva is half-grown) respiration is purely cutaneous. The gut consists of a tube constricted so much at the proctodæum as to be blind, free communication not existing between stomach and rectum. The rectum in its posterior region gives insertion to two Malpighian tubes which run forwards towards the thoracic region. As will be shown below (p. 394), there are no tubes of any kind attached to the hinder region of the gut.

The jaws in the live specimens may be seen to be continually in motion, and serve to break up the fat-body of the host caterpillar.

The heart contracts from the back, forwards, and one can see the blood liquid from the vesicle passing into the openings in this region to go forwards.

There is nothing peculiar about the nervous system except that the abdominal chain does not enter the vesicle.

When the larvæ of *Apanteles* are a certain size cutaneous respiration does not suffice; it is at this moment that the tracheal tubes fill themselves with

air and carry the latter to all parts of the body. The respiratory system is identical in all the *Microgasteridæ* observed by Seurat. It consists of two longitudinal trunks on each side of the body, united in front by a cross tube, dorsally to the digestive tube, but not united in the hind region of the body. Each trunk gives rise to eleven branches, latero-dorsally and latero-ventrally situated in each segment from number two to number twelve. A branch from each trunk is given off and ramifies into the anal vesicle. The nine pairs of latero-dorsal trunks situated in segments two to eleven present, near their place of origin and just laterally, a short accessory trunk, blind at its extremity; these accessory trunks, nine pairs in number, are the stigma tubes, but during the whole of the life of the larva inside the host they remain blind, the tracheal system being entirely closed. At the moment of the exit of the parasitic larva from the body of the caterpillar, the stigma trunks, with the exception of the second pair, open to the exterior; the first pair is in the anterior region of the mesothorax, the seven others on the anterior part of the first seven abdominal segments.

Seurat did not properly examine the larva by the section method, and since he has written on so many forms in a fairly short paper, his treatment of *Apanteles* larva is somewhat curtailed and unsystematic, but is nevertheless the best extant. Seurat's description of the tracheal system is very fine, but I disagree with him in certain ways (page 399).

Personal Observations.

a. Material and Method.

My material for this study consisted of a large number of larvæ of *Microgaster connexus* and a certain number of *Apanteles glomeratus*. *Porthesia similis* larvæ were collected; they were opened, and the parasitic larvæ where they occurred were transferred to various fixatives. The smallest caterpillars contained, on the whole, the smallest and least developed parasitic larvæ; the large full-grown caterpillars contained nearly or quite full-grown parasitic larvæ. Bouin, Flemming, corrosive-acetic, Petrunkevitch, Carnoy, and 3 per cent. bichromate of potash were used. Whole mounts were stained in Paracarmine, sections in Ehrlich's Hæmatoxylin, or Iron Hæmatoxylin. For a study of the fat the Flemming-fixed larvæ were very useful.

b. The External Morphology of the Larvæ.

In dissecting the caterpillars it is found that the parasites generally lie evenly disposed along the length of the hæmocœl. If they are only half-grown the fat-body of the host is still well developed and the parasites are mixed up among the bundles of fat-cells. In full-grown parasitized caterpillars the fat-body is either poorly developed or not present at all. The

FIGS. 1-5.

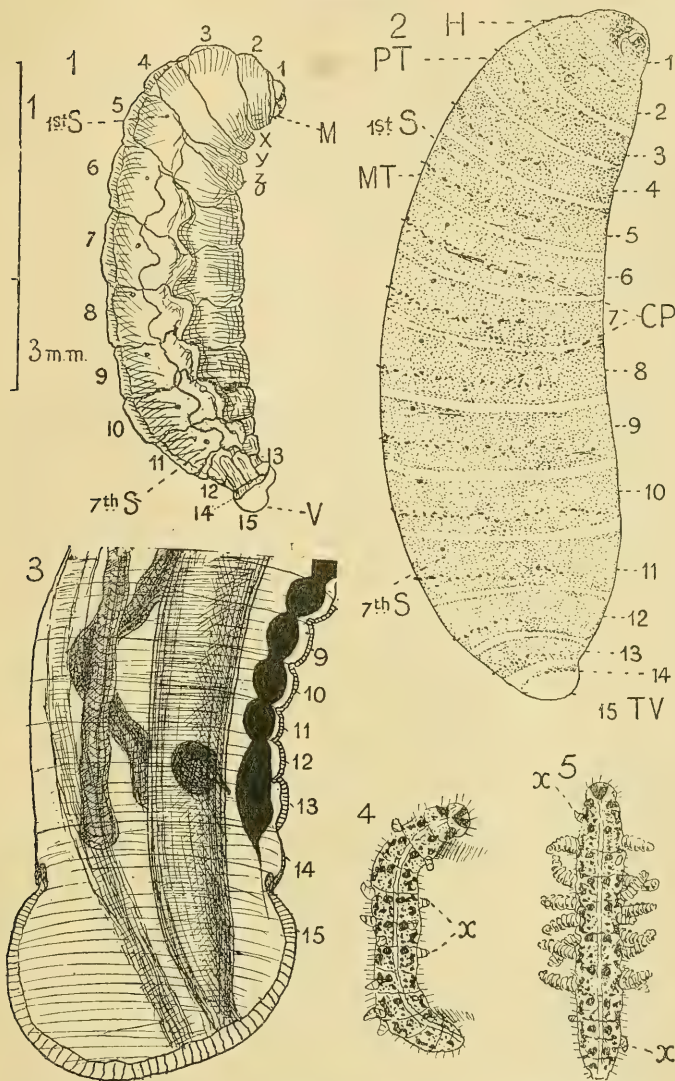


Fig. 1. Larva of *Apanteles* after emergence from *Pieris* caterpillar (Fig. 5) and before spinning up. The vesicle is at V; *x*, *y*, and *z* are the thoracic segments.

Fig. 2. Potash preparation of adult larva of *Apanteles* to same scale as previous figure. The chitinous papillæ (CP) are shown in each segment. MT = metathorax. TV = vesicle. PT = prothorax. H = head segments.

Fig. 3. End of the body of young larva to show the segments in relation to the nerve-chain.

Figs. 4 & 5. Successive stages in the emergence of the *Apanteles* larvæ (*x*) from the body of the host Pierid caterpillar.

In these figures the scale on the left top corner refers only to the two upper figures.

tracheæ of the host and the muscles and connective tissue of its abdominal cavity are untouched.

The larvæ when dissected out are transparent white objects, which are incapable of very active movement. They are able alternately to contract and relax the lateral muscles of each side of their body so as to produce a slow wriggling movement. In all the larvæ examined the terminal abdominal body is seen to be specialized in that it is expanded to form a bladder, which differs in size at different stages of the larva's life.

In Pl. 24. fig. 3, *a* to *h*, are eight larvæ drawn at a magnification of eight diameters. At *a* is the smallest larva I found; it is drawn at a much greater magnification in Pl. 26. fig. 16. The tail bladder or vesicle is not externally conspicuous. Gradually as the larvæ grow, the bladder becomes larger and larger in proportion to the size of the other segments of the body, till as in Pl. 24. fig. 3, *e* and *f*, it becomes a remarkable object. From the stage in *f* the bladder no longer grows any larger, and soon afterwards it begins to become absorbed (*g*). By the stage in *h*, it is only a small projection at the ultimate segment of the body, and when the larvæ are full-grown and ready to bore their way outside the body of their host, the vesicle, while still demonstrable, is very small—its part has been played (see text-figs. 1 & 2); the larvæ pupate in the ordinary way, and I could find no sign of the vesicle after examining the externals of a number of pupæ.

c. The Anatomy of the Larvæ.

The number of segments in the larva is a most difficult matter to ascertain. Seurat thinks that altogether there are thirteen, counting head and terminal vesicle. In the young larva drawn on Pl. 26. fig. 25 there were fourteen segments, counting head and vesicle. The same seemed to be the case with all the larvæ I could examine. I believe that there are, one head, three thoracic and ten clear abdominal segments—counting the bladder as a segment. Seurat's figure gives nine abdominal segments, counting the bladder. I think Seurat may have made a mistake, for I have made very careful observations specially to solve this question (see also p. 400).

The head, thoracic and first nine abdominal segments are quite normal; "segment ten" of the abdomen is inserted into the ninth by a "bottle-stopper" joint. This can be seen in Pl. 25. fig. 10 and Pl. 26. fig. 25. In the embryonic larva the tenth segment is larger than any of the other abdominal segments, and its walls are very thick (Pl. 26. fig. 25).

d. The Alimentary Tract is very peculiar. It is entirely made up of hypertrophied cells. The œsophagus and buccal mass (BM., Pl. 24. fig. 6) are normal; there is an œsophageal valve, which is poorly developed, but the œsophagus does not lead straight into the mesenteron (mid-gut). In all

probability the œsophageal valve can be used effectively to prevent regurgitation of food, when this is desired. The mesenteron is widest near the thoracic region and tapers backwards imperceptibly, being attached in the ultimate abdominal region to the ventral inner surface of the abdominal vesicle (Pl. 24. fig. 6 and Pl. 25. fig. 10). There is no differentiation of the hind region of the gut into a proctodæum (rectum), and no apparent Malpighian tubules could be discovered. The gut is drawn in Pl. 24. fig. 6, M, and in Pl. 26. fig. 24. The hinder region of the gut is attached to the bladder, as shown in Pl. 25. fig. 10 in sagittal section, and there is now no vent or anus. In the region of attachment of the hind region of the gut are muscle bannerets which pass from the external muscle-layer of the gut to the connective tissue which lines the inner walls of the vesicle. These muscles are not apparently of the same nature as the circular muscles of the gut. In Pl. 25. fig. 11 the gut (GT) is cut in transverse section in the hind-thoracic region. • The black bodies are the nuclei. The gut contains a finely granular mass of food, with oily vacuoles here and there, and occasionally the fragmentary nuclei of the masticated fat-body cells of the host caterpillar.

In Pl. 25. fig. 10, the slightly oblique section of the hinder region of the *Microgaster connexus* larva illustrates very clearly the disposition of fat in the gut and body. This larva was preserved in Flemming's fluid, and the osmic acid has blackened the fat. In the gut the finely granular food is seen to have an immense number of fat droplets in it. The gut-wall itself has a large number of big fat droplets in it. The fat-body (FB) of the larva also contains a great deal of fat. Fat-absorption takes place along the whole length of the gut, right to the region of attachment of the hinder gut to the wall of the vesicle. It will be noticed in Pl. 25. fig. 10 that the vesicle contains no fat, the dark spots in it being the large nuclei.

In Pl. 26. fig. 22 (MN) the histological structure of the gut-cells may be seen; each gut-cell (MN) is very large, extremely vacuolated, and the nucleus is a crenated structure, as is fairly common in fat-cells but rare in the alimentary-tract cells.

In most insects though the proctodæum and stomodæum are lined with chitin, the mesenteron also has a modified lining or intima, which, if it is not chitinous, quite often resembles chitin. In some cases, as in the mesenteron of the adult Braconid (*Aphidius*), I have discovered a lining which is so like a ciliated layer, that all those to whom I have shown the sections have pronounced them to be cilia or wonderfully like them. But when the live animals were teased up in salt solution, though the pseudo-ciliated lining could be seen, there was no ciliary action. Statements with regard to the nature of the lining in the gut of *Microgaster* are difficult to formulate. The stomodæum is lined by a very thick layer of chitin (text-fig. 14); the entire length of the mesenteron also seems to have a chitinous (?) intima of the thickness of about half that of the œsophagus

(text-fig. 15, p. 411); very careful observations were made with regard to the lining of the mesenteron. In Pl. 25. fig. 10 the hinder region of the mesenteron is drawn, in Pl. 25. fig. 11 the metathoracic region; in both cases the same apparently chitinous intima is found.

e. The *Spinning Glands* are remarkable; they consist of two pairs of tubular structures stretching from the buccal mass to the seventh or eighth abdominal segment. In the region of the metathorax (X) the two pairs of glands join up to form a single pair of ducts, which open into the inside of the buccal opening (Pl. 24. fig. 6, SG). The silk glands, which as is well known are modified salivary glands, are peculiarly and extremely well developed in the Microgasteridæ. In Pl. 25. fig. 11 the glands (SG) are cut in transverse section. In Pl. 26. fig. 24 the right pair of glands and their common duct (CD) are diagrammatically drawn.

At the stage in Pl. 24. fig. 6 the *Imaginal Discs* are well developed. It is not intended to describe them here at length; in Pl. 24. fig. 6 there are head-pairs at IDA, 3 leg-pairs at ID1 to ID3, wing-pairs (W^1 , W^2), and in the posterior region of the body there are pairs [near the gonads, G in Pl. 24. fig. 6]. It is these pairs which are of interest in this paper, for they provide evidence with regard to the proper solution of the problem as to whether the terminal vesicle is itself a segment. The imaginal discs of the hind region of the body are found in the segments marked 13 and 14 in Pl. 24. fig. 6. In text-fig. 3 the imaginal discs could be seen on a level with the large ultimate nerve-chain segment. No imaginal discs were seen in the vesicle.

r. The *Heart* is not in any way peculiar in the front and main part of the body of the larva (Pl. 25. fig. 11, H), but in the hind region within the terminal vesicle it becomes modified. In Pl. 24. fig. 6 the heart is the white line at H. In Pl. 26. fig. 22 the transverse section of the vesicle shows that the heart (H) is extremely wide here, and at each side of it is a bunch of cells of a glandular nature. In amongst these cells are other larger cells, which are blood corpuscles. The heart appears to open into the bulb in several places, and the bunches of cells may be part of the mechanism of valves. Towards the region where the bulb enters the eighth abdominal segment the heart rapidly narrows, till further on, in the hinder abdominal segments, it assumes its normal proportions. In Pl. 25. fig. 10 the heart, which is just above the gut, does not probably lie in its normal position; this may be due to shrinkage, for it is a most difficult matter to keep the thin stretched bulb from becoming distorted as the larvæ are being embedded. In Pl. 25. fig. 10 the heart should lie just on or near the upper surface of the gut, as in Pl. 26. figs. 22 and 24.

g. The *Nervous System* is not peculiar; the only matter which need interest us here is the question of the position of the last ganglia in the

ventral chain. As shown diagrammatically in Pl. 26. fig. 24, the ventral chain ends at NY, just near where the bulb joins the ninth abdominal segment; the chain does not continue into the vesicle. In text-fig. 3, p. 393, a profile view of the last segments of the abdomen shows that the last ganglionic swelling is in segments twelve and thirteen, and lies in both; this was very clear especially in one case. The point to be noticed is that no ganglia are found in the penultimate or ultimate segments of the larva (counting the bulb as a segment).

The *Gonads* lie in the eighth abdominal segment (Pl. 24. fig. 6, Pl. 25. fig. 10, G) and open by a short duct in this region. The duct is solid and only forms a blind connection between epidermis and gonad, at this period (see Pl. 26. fig. 24, G). In the embryonic larva the gonad is a most conspicuous object (Pl. 26. fig. 25, G).

h. Though I have been able to add many new facts with regard to several other parts of the anatomy of the larval *Microgaster*, the main purpose of this paper is to describe the *Abdominal Vesicle*.

The latter is a most remarkable organ, and I have come to the conclusion, with some other observers, that its function is respiratory. Its gross outer morphology at different stages has been reported upon already and is shown in Pl. 24. fig. 3, a-h.

In Pl. 24. fig. 6, the vesicle is seen to consist of very large polyhedral cells with large, often irregular, nuclei. The cells are largest at the outer and middle regions of the bulb, and where the latter tapers to join the ninth abdominal segment, the vesicle cells become smaller till they pass imperceptibly into the ordinary hypoderm cells of the larval body. In Pl. 24. fig. 6, the ordinary hypoderm cells in the head, thoracic and body region were too small to be seen individually, but in the bulb they were easily drawn in with the camera lucida.

The largest vesicle cells were 90μ in their greatest length and their nuclei attained a diameter of 40μ .

The *Histology of the Vesicle Cells* is very remarkable. In Pl. 25. fig. 12 are four cells from the region enclosed by the square in fig. 10. On the outside of the cells of the vesicle is a cuticular chitinous layer (OC) which in larvæ of various ages differs in thickness. The cells in Pl. 25. fig. 12 were fixed for four days in 3 per cent. bichromate of potash. Just below the outer cuticle the vesicle cells have a granular darkly staining zone (GLX) which cannot be found in material preserved in alcohol-acetic fixatives. The rest of the cytoplasm is clearer, but in some cases seems to contain granules (mitochondria?), while in other cases I have found a large siderophile granule, insoluble in acetic acid. The nucleus is large, pale, finely granular, often irregular, and does not contain a karyosome or plasmosome. The inner edge of the cytoplasm is drawn out in a remarkable

manner into a large number of processes which in section look like the teeth of a comb. These processes rest on a layer which seems in some cases to be a cell-wall, in others a layer of connective-tissue cells finely drawn out; at all events the teeth of the comb are joined together by a distinct line as drawn in Pl. 25. fig. 12. The inside of the vesicle is lined by a network of connective-tissue cells which join on to muscle bannerets and to the cardiac region.

In Pl. 25. fig. 14 is a part of the vesicle-wall drawn at a lower power than fig. 12, from material fixed in Gilson-Petrunkewitsch. The outer chitinous layer is thicker than in the case of fig. 12, there are the same cell processes, but at F.E., where in fig. 12 was the outer granular layer, is a curiously frilled edge to each cell; no granular layer could be found, and the exact relationship of the frilled layer and the granular layer is difficult to ascertain.

In Pl. 25. fig. 13, a part of the ordinary body-wall in the mid-abdominal region is drawn, and is magnified the same amount as Pl. 25. fig. 12. The immense size and thickness of the vesicle cells now become clear. Fig. 13 represents the ordinary type of hypoderm found in Hymenopterous and other insect larvæ.

Seurat (13) described a pair of *Malpighian tubes* in his larvæ; what he supposed to be Malpighian tubes are not connected to the gut, but are the tubes marked Tx in Pl. 24. fig. 6. The most careful search in sections and whole mounts failed to reveal any typical Malpighian tubes, and Seurat has made a mistake (see page 399). Sections of the vesicle, however, show two organs very like Malpighian tubes. These *Vesicle Glands* are shown in Pl. 26. fig. 22 GL, in a transverse section of the hinder region of the vesicle. At Tx are cut the structures thought by Seurat to be Malpighian tubules. The vesicle glands are a pair of somewhat coiled tubes which open to the epidermis on the dorsal region at each side of the dorsal vessel (heart).

In Pl. 26. fig. 20 is a diagrammatic plan of a section of the region just where the bulb joins the ninth abdominal segment; this region is between the letters M—O in Pl. 24. fig. 6. In the section in Pl. 26. fig. 20, dorsal and ventral are shown by the letters D and V. The heart is at H, the gut at GT, the vesicle glands are at GL in the form of black dots (in section), and at the region X at each side of the heart the duct opens to the exterior. The region X is drawn in Pl. 26. fig. 19 at a high power. The gland is at GL, the heart at H and the opening at O. The region above the heart is just here flattened or even depressed in a peculiar manner as shown in Pl. 24. fig. 19, and it is just where the ordinary enlarged vesicle cells join the flattened region that the vesicle glands open to the exterior (compare fig. 19 and fig. 20). The vesicle glands stain darker than the epidermis (hypoderm). In Pl. 24. fig. 6 the vesicle glands are seen at GL, the opening at O. In Pl. 26. fig. 21, is drawn a transverse section of the vesicle

gland. It looks exactly like a Malpighian tubule, and in its length it is covered by a layer of epithelial cells (maybe mesoderm) which are shown in fig. 21. There are four or five cells in the transverse section of the gland tube, but no crystals or urates could be seen in the gland cells. The origin of the gland could not be worked out, but it is probably an epidermal ingrowth. In Pl. 26. fig. 24, the gland is shown diagrammatically at GL, the opening at O. (See also page 411.)

i. The body-cavity of the larva is occupied by a large *Fat-body* which is shown in Pl. 25. figs. 10 & 11, F.B. No fat-cells are found in the vesicle during early or middle larval life. The fat-body is of the usual type found in hymenopterous larvæ. The nuclei are somewhat branched, and the fat-body lies in the form of several lobes.

In Pl. 24. fig. 6 the fat-body is not drawn, but it would pack around the various tubes and glands drawn from the letter ID 1 to the letter G.

The Tracheal System.

In the adult larva there are seven stigmata, as in text.-fig. 1. The first is on the metathorax, the rest follow on the other abdominal segments behind. The last stigma is on the sixth abdominal segment. Seurat says other stigmata exist, and mentions that just before pupation of *Microgaster* another stigma opens. In Pl. 24. fig. 6 the tracheal system is drawn in, somewhat diagrammatically. The two lateral trunks (T) give rise to at least seven stigmal trunks (1st S, 7th S), but for any others I cannot speak. Seurat describes in all nine stigmal trunks, but my text-figs. 1 and 2 do not agree with his description quoted by me on page 391. I regard my evidence, gathered as it is from sections, potash preparations, and from whole preparations, as irrefutable especially with regard to the stigmata in the adult larva. Seurat's account seems based particularly on *Microplitis*, and quite possibly his statement that the tracheal systems of all the *Microgasteridæ* is similar, may be incorrect. This would account for my inability to agree with his description of *Microplitis seurati*.

The Malpighian Tubes (?) of Seurat.

If Pl. 24. fig. 6 be examined it will be seen that two tubes are to be found running parallel to the hinder region of the gut, marked Tx. At the vesicle region they join the vesicle wall at Tx. In Pl. 25. fig. 10 these tubes were not cut in the obliquely sagittal section, but I have drawn the left-hand one in at Tx to show its relations with the gut. These tubes do not join the gut at any part of their length. They end near the first abdominal segment, where they taper more or less to a point. This last fact is rather important. I will call these two tubes the "enigmatic tubular glands," till their true

nature has been elucidated (see page 411, where I have mentioned a possible explanation of their nature). In Pl. 26. fig. 25 these glands are drawn in a very young larva, and their position of insertion into the vesicle wall and not into the gut was very clear. In Pl. 26. fig. 22 these glands are cut across at Tx, below, or to the sides of the hinder region of the gut. In Pl. 26. fig. 23 is a high power drawing of the upper part of one of the tubes in fig. 22, Tx. There are about three flattened cells in the section, their cytoplasm is somewhat striated, and in the lumen is an irregular fringe or intima (C). Whether it is chitinous or not I cannot say. The main point to notice is that these glands in *Microgaster* do not join on to the hind region of the gut, as claimed by Seurat.

Embryonic Membranes of Microgaster.

In Pl. 26. fig. 16 is drawn the youngest larva I found. The larva is externally completely segmented, but it is covered by an embryonic membrane consisting of large stretched cells. Likewise the larva in Pl. 26. fig. 25 is covered by a cellular membrane (S). In the larva in Pl. 26. fig. 16 there are also at A a number of hypertrophied loose cells. Not having any stages earlier than that in Pl. 26. fig. 16, it is not possible to say for certain what these loose cells represent; possibly the outer membrane is the serosa, the hypertrophied cells at A, the amnion. In certain *Platygastrs* (15) the egg divides into parts, one of which gives rise to the embryo, the other to hypertrophied cells. In *Microgaster* the outer membrane, which is probably a serosa, may be found in larvæ up to $2\frac{1}{2}$ mm. in length, and may act as a medium for nourishing the embryo up to time when it is ready to begin feeding on the fat-body of the caterpillar.

The proper identity of the membrane or membranes and their method of origin could not be worked out because my material was all too far advanced. However, it is important to recognize that the embryonic membrane persists for a remarkably long time during which the larva does not feed, all nourishment being derived through the instrumentality of the membrane. This is undoubtedly a specialization due to the larva's mode of life. It should also be noticed that though the membrane envelops the larva's body much later, this does not say that food is not being taken in during later stages, for the larva could bite a hole in the membrane. I think food is not taken in till the larva is 2 mm. in length. Full-grown larvæ are some 5 mm. in length.

The Segmentation of the Larval Microgaster connexus.

The question of the segmentation is one of the greatest difficulty to elucidate, and special care has been taken by me to ascertain the number of segments.

If the adult *Apanteles* larva after emergence from the *Pieris* caterpillar

be examined, it will be seen that there are seven stigmata, the first on the fifth segment of the body (text-fig 1, p. 393), the others on the following six segments. The vesicle is still quite clearly marked though much shrunken; the number of segments is difficult to ascertain with certainty in such specimens. If larvæ are boiled in 10 per cent. potash solution till only the chitin is left, most instructive preparations are procured: in text-fig. 2 there is drawn the skin of the adult larva; segments are clearly marked by the pale line where the chitin thins out to form the joint; in such preparations there are to be seen fourteen segments altogether where the chitin alternately thickens and then becomes thin. The first stigma is on segment five, the last on segment eleven. The posterior abdominal region is instructive also; we see a clear thirteenth segment, then a pale joint, then a very narrow but perfectly demonstrable segment, and finally a pale bulb—the terminal vesicle. Now it will be seen that each segmental ring has a row of chitinous areas or teeth, situated behind the stigma, if this is present in the segment. The first segment has no row of teeth (text-fig. 2), the second and succeeding ones, even to the small fourteenth, all have these chitinous papillæ or teeth. Inspection of Pl. 24. fig. 6 shows that the brain does not altogether lie in segment one; part of the brain lies in segment two; moreover, in segment two there are no imaginal discs. It seems certain that segments one and two both go to form the head, segment three is the prothoracic, segment four the mesothoracic, segment five the metathoracic. The imaginal discs of the wings (W) are in the meso- and meta-thorax, those of the legs from the third to the fifth segments. Re-examination of the potash preparation in text-fig. 2 now shows that the first stigma is on the metathoracic segment, the following six on first six abdominals. After the thoracic segments there are ten abdominal segments, counting the vesicle as a segment. Seurat (12) makes nine abdominals, but figures a ring in his drawing on page 65, fig. 11, which is undoubtedly the little segment, fourteen, which I have shown to have proper chitinous papillæ, and which is undoubtedly a true segment.

As for other abdominal segments, it is possible that the "bottle-stopper" joint drawn in Pl. 26. fig. 25, at 9, may be partially or wholly formed of degenerate segments. The evidence of early embryonic stages might be conclusive with regard to this point.

A Hyperparasite (Mesochorus pallidus, Brisch.) of Microgaster connexus.

In Pl. 24. fig. 6, at HP, inside the body-cavity of the *Microgaster* larva is another, hyperparasitic larva. In Pl. 25. fig. 11 is a hyperparasite at X in transverse section. Cocoons of *Microgaster* bred by me in the laboratory produced some *Microgasters* and also another insect, *Mesochorus pallidus*, which is drawn in Pl. 25. fig. 7. The hyperparasitized cocoons can be

detected, as already explained, by the jagged hole through which the insect has escaped (compare Pl. 24. fig. 1 and Pl. 25. fig. 9). *Mesochorus* is not a Braconid or a Chalcid; it belongs to another group of Hymenoptera, the Ichneumonidæ. Superficially it is (when the specimens themselves are cursorily observed) very like the parasite *Microgaster*, but further examination shows differences in the venation of the wings, etc.

In Pl. 24. fig. 4 the host caterpillar (*Porthesia similis*) is drawn, and near at HP is the hyperparasite to the same scale. The parasitic larva, *Microgaster*, lies inside the hæmocœl of the caterpillar: how does the hyperparasite contrive to lay its eggs inside the body of the parasitic larva *Microgaster*? A certain percentage (about 10 per cent.) of the latter were hyperparasitized. The only solution of the problem that I can suggest is that the Ichneumon bores into the host caterpillar (*Porthesia*) till it feels a parasite (*Microgaster*) with its ovipositor, and that it thereupon lays an egg inside the parasite.

It is to be noticed that the hyperparasitic fly must be very skilful in ovipositing eggs inside the parasites, for I judge that the host caterpillar must be nearly full-grown when the parasites (*Microgaster*) are hyperparasitized, and there is no doubt that unless the hyperparasite was most circumspect the host caterpillar would struggle, and the movements of its body-wall muscles would possibly prevent the Ichneumon from successfully ovipositing in the body of the parasitic Braconid. If about 10 per cent. of the *Microgaster* larvæ are hyperparasitized, it must be noticed that this would mean that the Ichneumon would need to pierce at least five holes in the *Porthesia* caterpillar in order to lay its eggs in the parasites, and it is doubtful if at every piercing of the epidermis of the caterpillar, it would locate a *Microgaster* parasite. The latter parasites lie here and there in the fat-body of the host; the *Porthesia similis* caterpillar is a stout, bristly creature, and though the parasitic *Microgaster* was faced with a difficult task in ovipositing inside the caterpillar, it only had to make one hole: how much more difficult is the task of the Ichneumonid *Mesochorus*? It must needs seemingly pierce a number of holes, and attack a much larger strong caterpillar covered with bristly warts (Pl. 24. fig. 4).

All attempts to get either parasite or hyperparasite to oviposit while in captivity completely failed, the insects were so timid.

The *Position of the Hyperparasitic Larva in the Parasitic Larva* was never constant, in some cases it lay in the thoracic or abdominal regions, in others in the terminal vesicle (Pl. 25. fig. 10). The youngest parasitic larva hyperparasitized was about the size of that in Pl. 24. fig. 3 d. The hyperparasite never killed the parasite till the latter had spun its cocoon; this is why only fairly old parasites become hyperparasitized. The parasite is used by the hyperparasite till the former has spun a protective cocoon for the latter—not only does the hyperparasite use the body of the parasite, but it makes use of the latter's skill in spinning a beautiful strong silk covering.

Hyper-hyperparasites and Other Hyperparasites associated through Microgaster and Mesochorus, etc. with Porthesia and Pieris.

If the silk pupa-cases of Microgasteridæ, *Microgaster*, *Apanteles*, etc., be collected from their natural positions on walls and tree-branches and kept in bottles, it will sometimes be found that apart from the Microgasters and Mesochorids one may breed out other hymenopterous insects. In certain cases the evidence goes to show that some of these insects are hyper-hyperparasites. This is to say, that the insect which attacked the parasitic *Microgaster* (the hyperparasite) has in its turn been attacked by another parasite which is therefore a hyper-hyperparasite.

I have not bred *Mesochorus pallidus* from *Apanteles glomeratus* cocoons, but there is another Ichneumon, hyperparasitic on *Apanteles*, which I have bred, and this evidently stands in the same relationship to *Apanteles* as *M. pallidus* does to *Microgaster connexus*. For a good memoir on the parasites, hyperparasites, etc., of *Pieris brassicæ* the reader is referred to Martelli's bionomical account (3).

Mr. G. Lyle, of Cambridge, kindly writes that he has long suspected the presence of hyper-hyperparasites in connection with *Microgaster*. He bred some Chalcids (*Pteromalus*) from the cocoons of *M. connexus*, which he considered to be hyper-hyperparasites because the whole of the cocoons in the brood which did not produce Chalcids yielded hyperparasites.

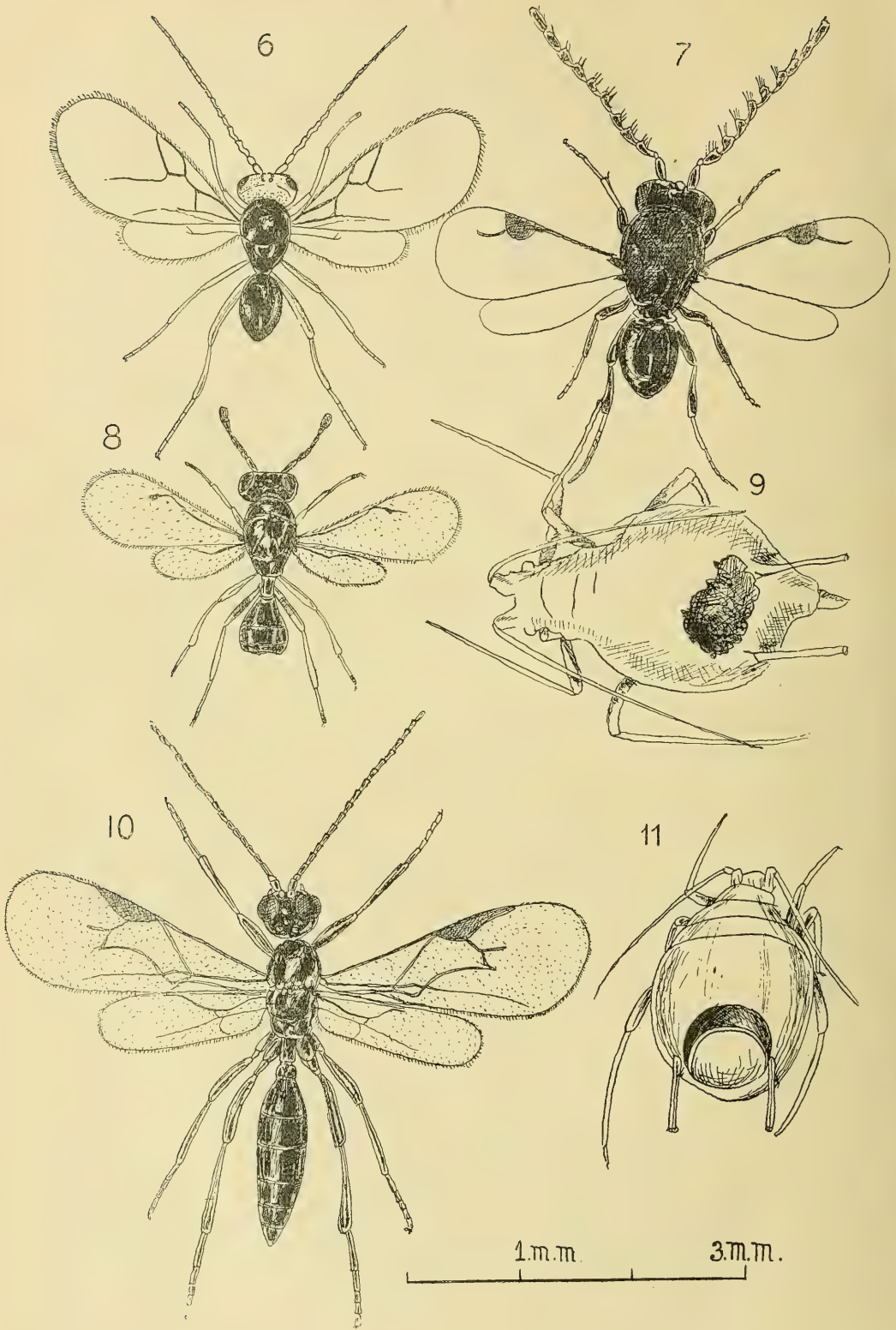
Mr. Lyle also records that he has bred a Chalcid of the genus *Cirrospilus* (Westwood) from the cocoons of *Apanteles juniperatæ* (Bouché), which he believes to have been a hyper-hyperparasite through *Parnargyrops aereus* (Grav.).

It will be seen that the lives of these parasites, hyperparasites and hyper-hyperparasites are confusedly interwoven, and the correct understanding of the various bionomical problems in this connection will need special and careful study. It seems clear that some of the hyperparasites are also sometimes hyper-hyperparasites in other cases, according to the contents of the pupa-case or cocoon they are attacking. The correct observance of the habits of the parasites, hyperparasites, and hyper-hyperparasites of injurious and beneficial insects such as the Cabbage butterfly (*Pieris brassicæ*) are of great economical value, and will open a wide field for the embryologist and cytologist, (3).

Note on Parasitism, Hyperparasitism, etc., by Hymenoptera among Aphidæ (Plant Lice).

If a colony of Aphids on a leaf or branch be examined, it will be found that among the living Aphids are to be seen dead individuals whose bodies may be somewhat swollen, which are a light straw-brown colour, and which

FIGS. 6-11.



may often be observed to have been pierced by a round hole. Those dead Aphidæ which have no round hole in them, when collected and kept in stoppered phials, will be found sooner or later to give rise to small Hymenopterous insects, generally jet-black. In text-figs. 6-11 are drawn four of these minute insects; study of these forms shows that the parasitic species are mostly Braconidæ belonging to the genus *Aphidius* (text-fig. 10). The flies belonging to this genus always seem to emerge from the dry carcase of the Aphid by means of a neat round hole and a distinct lid (text-fig. 11). Now there are other small black flies which emerge from these Aphid carcasses, and which are not Braconidæ (*Aphidius*). These, in the cases examined by me, almost always seem to be hyperparasites on the *Aphidius* (text-figs. 6 & 8). All the flies which emerge from the Aphids, and which are not Braconidæ, are either Chalcids, Cynipids, or Proctotrypids, and these leave the dry carcase of the Aphid by making a rough hole without a lid (text-fig. 9). This may be compared with the peculiar case already mentioned in connection with *Microgaster* and *Mesochorus*, Pl. 24. fig. 1 & Pl. 25. fig. 9, where the same thing also happens with regard to parasite and hyperparasite.

The Ichneumonidæ are another family of parasitic Hymenoptera which attack caterpillars and other larger insects. From an examination of the literature, and from the personal experience of observers in the Hope Department, Oxford, and of myself, I do not think any Ichneumons prick Aphids. Aphid hymenopterous parasites are all from the Braconidæ, Chalcididæ, Proctotrypidæ, or Cynipidæ. It seems certain that the majority of, if not all, Chalcididæ associated with Aphidæ are hyperparasites, while the Cynipidæ, represented by forms like *Allotria flavicornis*, are possibly all hyperparasites also. The Aphidiidæ (Braconidæ) are all parasites as far as I know; the case of the Proctotrypidæ is still doubtful. Mr. Britten, of the Hope Department, considers that these forms are parasites and not hyperparasites.

Explanation of Text-figs. 6-11 (page 404).

Hymenopterous parasites and hyperparasites associated with Aphidæ (Plant Lice).

In text-fig. 10 is the typical parasite, a Bracon, *Aphidius avenæ* (Hal.). All the other hymenoptera in these figures are possibly hyperparasites on the Aphidiidæ (Braconidæ).

In text-fig. 6 is *Allotria flavicornis* (Htg.), which is neither Bracon, Chalcid, nor Ichneumon, but belongs to the Cynipidæ or Gall-flies.

In text-fig. 7 a Proctotrypid, *Ceraphron carpenteri* ♂ (Curt.) is drawn. Whether a parasite or a hyperparasite is not known.

In text-fig. 8 is a Chalcid hyperparasite (on an *Aphidius*), *Asaphes vulgaris* (Nees).

The Aphidiidæ emerge from the dry aphid-skin by means of a round, cleanly cut hole with a lid on one side, as in text-fig. 11. All the other insects drawn in these text-figures, Chalcids, Cynipids, and Proctotrypids, emerge from the dry aphid-skin by a rough hole, as in text-fig. 9. (Compare Pl. 24. fig. 1 and Pl. 25. fig. 9.)

Other Proctotrypids are known to be parasites of insect larvæ (15); and I am inclined to support the view that the Proctotrypid is a parasite and not a hyperparasite. I have been able to prove that *Allotria*, the Cynipid, is a hyperparasite.

The Cynipid parasitic forms associated with Aphids apparently never attack live Aphidæ, but seek out the dried skins of those already parasitized by an *Aphidius*. The same applies to many Chalcids. The latter insects, as far as my own experience goes, rarely attack active insects: I use the word active in the sense that the host is able to retaliate. For instance, the Pteromalids are Chalcididæ most often found pricking pupæ, which of course are unable to protect themselves. In the same way insect eggs, sluggish coleopterous larvæ, the pupæ of other parasites (*e. g.* Microgasteridæ), and the parasitized carcasses of Aphids are all objects of interest to Chalcids, and in every case the victim is unable to resist.

Chalcididæ are often spoken of as attacking live caterpillars, but all the polyembryonic forms lay their ova in the eggs and not in the young larvæ of the host species. It is nevertheless true that some Chalcids do attack most difficult objects, but the majority of species are either hyperparasites, parasites on pupæ, or egg parasites. Imms (5) records carefully the parasitism of *Aphelinus* on a Coccid. However, a Coccid is not the sort of creature which could retaliate against its tormentor in any way, and the problem of oviposition before the Chalcid is much the same as when it is laying its eggs in the ova of other insects or in pupæ. The Braconid of the *Aphidius* type is an active, intelligent and busy insect; its habits are different from those of some Chalcids I have noticed, which are sluggish, slow to take wing, and which often examine their victim with meticulous and apparently unnecessary care; the Proctotrypidæ and Cynipidæ (the *Allotrias*) I have not observed closely. Imms (5) and Marchal describe the oviposition habits of certain Chalcids, and in every case the insect is extremely careful and slow at work. I found the same in *Trichogramma evanescens* (9). Of all the Parasitic Hymenoptera the Ichneumonidæ and Braconidæ are the cleverest and most artistic in their methods of attacking their proposed victims. The manner in which a wasp or an ant proceeds to capture and kill insects is rough as compared with the beautifully exact *modus operandi* of the *Aphidius* [or of the Pompiliidæ (fossorial wasps)].

The Parasitic Aphidius. (Pl. 26. figs. 17 & 18.)

The parasite may be observed walking most unconcernedly over a colony of Aphids, stopping here and there and then passing on; when it finds an Aphid which satisfies it, it attacks as shown in the above-mentioned figures. While this is going on, the unfortunate Aphid does not try to walk away, but it does move its legs, and often tries to kick. The Bracon takes not the

slightest notice, and with a rapid, hard, quivering stab pierces the Aphid, deep into its body.

If a number of half-grown Aphids be fixed in Gilson and stained in pararcarmine, on examination some will be found to contain parasitic larvæ as drawn in Pl. 26. fig. 15 at P. In all the parasitized individuals discovered by me, the larva is surrounded by an embryonic membrane, SA, and evidently does not feed till at a much later stage. In the lower figure in Pl. 26. fig. 15 is drawn in optical section the upper part of the parasitic cyst, the embryonic membrane (SA) is seen to consist of a single layer of hypertrophied cells.

In the case of certain Chalcids (13) this layer has been called the pseudo-serosa. The pseudo-serosa of Chalcids, where present, is derived by a delamination of the surface-cells of the embryonic morula, and it is more than likely that this membrane in the Braconid Aphid parasites is derived in a similar manner.

As the parasitized Aphids grow, they can frequently be detected by the fact that they become a little different in colour from their unparasitized fellows. In the case of *A. pomi*, which is brown, the parasitized forms become a whitish brown and the skin looks tight and shiny. Sooner or later these individuals leave off feeding and die, the parasite evidently having attacked their vitals. They then become the typical straw or darker brown shade. These dead parasitized Aphids, if opened up just after they have gone the straw-colour which characterizes them, are found to contain the Bracon larva. It is just at this stage, or some time afterwards, that the Chalcid and Cynipid hyperparasites begin operations.

The Hyperparasitic Chalcids and Cynipids seek out these dead parasitized Aphids, bore a hole in the dry skin and deposit an egg at the side of, but so far as I know never inside, the Braconid larva or pupa. The egg hatches out and the minute larva at once fixes itself on to the Bracon pupa or larva. If one examines enough of these dry Aphids, one is sure to find that in some cases the hyperparasite, even when quite young, may have a *Hyper-hyperparasitic larva* sticking on to its body. There is then a chain of three larvæ, or of one pupa (Bracon), a hyperparasitic larva (Chalcid or Cynipid), and a hyper-hyperparasitic larva (Chalcid?). Both hyperparasitic and hyper-hyperparasitic larva cling on quite firmly to the skin of their victim.

By collecting a number of the straw-coloured dead Apple-Aphids and keeping them in closed phials till the contained parasites, etc. hatch out, it will be found that a remarkably large number of small Hymenopterous insects depend for their existence on the colonies of plant-lice. It is needless to say that some of these insects are of great economic importance. The hyperparasites are not beneficial, as they are engaged in destroying the parasites, which are destroying the noxious plant-lice.

Discussion.

There is no doubt that the parasitism in Hymenoptera is a specialized development. In such a parasitism as we see in these insects there are two main facts which attract our attention:—In the first place there is the altered system of respiration, and in the second there is the food and excretion question. Non-parasitic insects are notable for their wonderful method of oxygenating their system by means of tracheæ, and for the large quantity of food which passes through their digestive system. In the case of internal parasitic Hymenoptera there is no defecation, and in most cases the relationships of the Malpighian tubes (if present) are altered (12). It is quite obvious that were these parasitic larvæ similar to other free-living forms in the extent in which they got rid of excreted matter, the system of the host would rapidly become poisoned. In *Microgaster* I have discovered a new organ, the vesicle glands, which very probably takes the place of Malpighian tubes, which are here quite absent as such. There is undoubtedly some matter excreted by these tubes, and set free inside the hæmocœl of the *Porthesia* caterpillar, but the Malpighian tubes of the latter are possibly quite able to cope with the extra work which would thus be put on them.

I have not yet made a comparative study of Malpighian tubes in parasitized and non-parasitized individuals, but probably it will be found that the tubes in the latter are either hypertrophied or fuller of excretory crystals than those of the non-parasitized caterpillars.

It must be remembered that the parasitic larva generally feeds on the fat-body of the host, and its food is therefore not likely to give rise to much defecatory matter. Digestion in *Microgaster* consists mainly of the assimilation of the fatty contents of the fat-body of the host. Evidently the defecatory matter remains in the gut till the anus opens later, but it must be pointed out that it would be a mistake to think that there was not something specialized in the digestive processes of the Microgasteridæ. Attention should be drawn to the fact that many predatory insects of a parasitic nature live by sucking the blood and juices of other insects which they capture, and such blood-sucking forms invariably defecate a good deal, although their food is as pure as it seemingly could be. A careful histological examination of the alimentary epithelia of several non-parasitic forms, and a comparison of these with that of *Microgaster*, leads me to consider that digestion in the Microgasteridæ is mainly a process of the transference of the small fat drops of the host fat-body to the vacuoles in the epithelium of the gut of the parasite.

Parasitized caterpillars, towards the end of their life, become sickly, and in many cases where there are bright pigment spots, these tend to be discoloured; the whole insect looks "out of condition," and such an appearance cannot altogether be due to the starvation of the system; rather would one suppose that the accumulated effects of the excreted matter of the

older parasitic larvæ was slowly poisoning the unfortunate host-insect, and so producing the peculiar discoloured unhealthy condition.

With regard to the question of respiration, there can be no doubt that the tail vesicle is respiratory in function. Seurat (12) thought that while the vesicle might be partly respiratory in function, it was at the same time a locomotor organ. I do not agree with the latter suggestion. Kulagin (16) thought that the vesicle was excretory in function.

There seems to be a good deal of "lipoid" matter in the vesicle cells; the outer granular cloud acts like the lipoids with fixatives and stains, and this is quite possibly the part of the cell which absorbs oxygen from the blood of the caterpillar. The cell processes on the inner surface of the vesicle cells are possibly a mechanism for increasing the surface of the respiratory cells, and so facilitating oxygen exchange between host and parasite.

Certain observers have considered that because the very young parasitic larva has no vesicle, the latter cannot be respiratory, for they consider if it were respiratory it would be necessary for, and present in the young. As a matter of fact, this line of argument is not of much value; many internal parasitic larvæ (*Litomastix* (13), etc. etc.) have no vesicle or other highly specialized arrangement for collecting oxygen from their host, and have adjusted themselves to their *modus vivendi* in another way. In one sense the larval Microgasteridæ are the most specialized of the Entomophaga in that they have the vesicle, but it is more than likely that the larvæ of *Litomastix* or *Encyrtus fuscicollis* (13), which have no vesicle, are really the most highly efficient sort of internally parasitic insect larvæ.

These creatures have solved the respiration problem in some way which does not require any peculiar morphological specialization. The bladder of *Microgaster* is a makeshift: the ultimate abdominal "segment" has been pushed into a service for which it was never intended.

The Tachinidæ, a family of Dipterous internal parasites of moth and butterfly larvæ, go about the problem in quite a different manner—they early become attached to one of the host's main tracheal tubes, so that their own tracheæ may take in air by means of the host's tracheal apparatus: this is a very clever specialization (17).

Dr. Boisduval (6), in some remarks on the manner of nutrition in the Entomophaga, likens it to that of a fœtus. I have in this paper brought forward the evidence of the embryonic membranes which persist for so long, and whose cells become hypertrophied. In a sense Boisduval is correct.

Attention should specially be directed to the remarkable adjustment in the course of development of the parasitic *Aphidius*, and the life of the host. In some ways the same applies to all Hymenopterous internal parasites of insects. We find that in early life, while the host is comparatively young, the parasites are enclosed in an embryonic membrane; it neither feeds nor defecates. All nourishment is gained by a process of absorption through a cellular embryonic membrane. The life and health of the host is hereby

guarded and temporarily conserved for the benefit of the parasite. In this we but find the usual relationship of host and parasite, which holds good among all animals.

Of the thirty or so parasites inside the body of the *Porthesia similis* caterpillar, not one attacks the gut or body-wall of the latter till the correct time has come; the parasites then are free to kill their host without at the same time being "hoist with their own petard."

Equally important is the question of excretion and defecation; in *Microgaster* I have shown the absence of the usual Malpighian tubules, and the presence of a pair of coiled tubes in the terminal vesicle.

With the exception of the fact of Hymenopterous polyembryony, which among other insects is unparalleled, it seems that the condition of the larval Microgasteridæ is the most highly specialized larval modification for an entomophagous life to be found in the Hymenoptera Parasitica.

The manner in which parasitism arose in the Hymenoptera in several different assemblages of forms is difficult to understand; the same applies to the parasitic Diptera, such as the Tachinidæ. Obviously the parasitic larva needs such a highly attuned and specialized system, that it is very difficult to understand how such modifications for the *modus vivendi* could have grown up. Moreover, the instincts surrounding the act of oviposition by one of these parasites are very wonderful. The instinct, which enables the newly emerged mother muscid to seek out meat or dung for its future offspring, has long been considered one of the noteworthy facts in bionomics of insects. How much more wonderful are the instincts which lead the newly-born adult *Microgaster* to attack, overcome and oviposit in the *Porthesia* larva it must find, that induce the Chalcid hyperparasite to seek out the dried bodies of Aphids which have been parasitized by an *Aphidius*!

The hyperparasite *Mesochorus* has a still more difficult task before it; not only have the *Porthesia similis* larvæ to be found, but one which has been parasitized must be detected, and then the larvæ inside the *Porthesia* caterpillar's body must be located and successfully pricked.

I have no evidence at present with regard to the question of defecation in later stages in *Microgaster* or *Aphidius*. Probably, at the time when the life of the Aphid or caterpillar is no longer necessary, the parasite voids the rectum. It should be noticed that in both the silken cocoon inhabited by parasite and by hyperparasite (Pl. 24. fig. 1 & Pl. 25. fig. 8) at F there is the fæcal pellet, as is usual. The vent possibly opens just at the time the larvæ are forcing their way outwards. Mr. A. H. Hamm informs me that there is a free-living fossorial wasp, *Psenulus*, which seems to feed up without defecating till full-grown; this probably happens in the dipterous genus *Cacoxenus*, and the habit is not therefore found only in true internal entomophagous parasites. So far as I know *Microgaster* larvæ do not regurgitate the waste food matter through their mouth.

*Some Speculations with regard to the Morphological Identity
of the Vesicle of Microgaster.*

Those authors who have examined these remarkable larvæ unanimously agree that the vesicle is the ninth abdominal segment, much enlarged. For one thing, I consider that these previous observers are incorrect in saying it is the ninth; as a matter of fact, even if it is really a segment, it is, I think, the tenth abdominal segment. But one is forced to question whether the bladder really is a segment.

Where is the proctodæum? Where are the Malpighian tubules? What is the homology of the vesicle glands?

FIGS. 12-15.

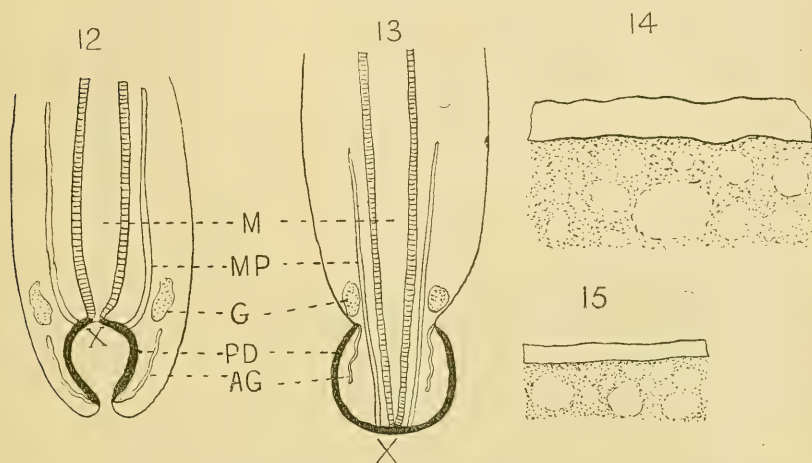


Fig. 12. Arrangement of the mesenteron (M), Malpighian tubules (MP), proctodæum (PD), anal gland (AG), and gonad (G) in typical insect larva.

Fig. 13. Position of these organs when the proctodæum is evaginated; compare positions of letter X in both figures. Fig. 13 represents the condition found in the *Microgaster* larva.

Fig. 14. Stomodæal lining.

Fig. 15. Mesenteron lining: both to same scale.

These questions alone serve to put us on our guard against the too rapid acceptance of the view that the bladder is a segment. In text-figs. 12 & 13 I give two drawings illustrating my tentative conception of the bladder as true proctodæum turned inside out. In text-fig. 12 the mesenteron (M), Malpighian tubules (MP), anal glands, and proctodæum (rectum) are shown in the ordinary position found in many insects. In text-fig. 13 the letter X drawn in the previous figure has shifted its position, and the outside of the vesicle is now what was really the inside of the rectum in the previous figure. By this evaginative process, the anal glands (AG) become placed just as the

vesicle glands of the bladder, and the Malpighian tubes take up the same position as the enigmatic tubular glands do in the larva of *Microgaster*. The gonad may or may not have altered its position: this is unimportant.

Facts supporting my tentative conception of the homologies of the vesicle, and vesicle glands of both kinds, in *Microgaster*, are as follows:—

1. No proctodæum is demonstrable in the larva, while a distinct stomodæum is present.

2. In Braconid larvæ (e. g. *Aphidius*) the number of Malpighian tubules is two, the same number as the enigmatic tubular glands.

3. It is hardly likely that the vesicle glands, which I consider excretory, are new formations. It is far more likely that they are direct modifications of some pre-existing organs (anal glands?).

4. In the larva no chitinous papillæ even of the finest description are to be seen on the vesicle. All other true segments possess them.

5. The bladder is not attached to the body in the same way that one true segment is attached to another. Instead, there is a curious “bottle-stopper” joint. If it were a true segment there is no reason, to my mind, why there should be a “bottle-stopper” joint instead of the ordinary joint. A “bottle-stopper” joint would automatically be produced by the invaginative process conceived by me.

6. Malpighian tubules are apparently, in insects, outgrowths of the proctodæum (*vide* Seurat's p. 70, fig. 12 (12)). The tubular glands are attached just at the correct region of the proctodæum if the vesicle be considered a proctodæum evaginated (see also MacBride's erudite work on “Embryology,” p. 260, for Malpighian tubes).

Special attention is drawn to Pl. 26. fig. 25, where the hinder region of the gut is seen not to taper in any way. There is nothing that could be interpreted as a proctodæal region in the shape of this gut.

Several facts which will have to be explained before we can adopt my present view with regard to the nature of the abdominal vesicle are as follows:—

1. There should be more segments than nine abdominals; (but the “bottle-stopper” joint might be formed of telescoped segments).

2. The enigmatic tubular glands (Malpighian tubes?) come to a point at their distal end. Malpighian tubes never, to my knowledge, do this.

3. If anal glands occur in Braconid larvæ of the ordinary type, they are either rare or have not so far been described.

With regard to the last statement, it is equally true that such vesicle glands (GL in Pl. 24. fig. 6) had not before been described by anyone.

The question as to the origin and true nature of the vesicle glands, enigmatic tubular glands, and of the vesicle itself, will be settled by examining early embryonic stages during the time the segments are appearing, and at the time when the proctodæum is in other insects becoming invaginated. Further work will be carried out on this interesting problem.

Summary.

1. Notes are given on the bionomics of certain Chalcididæ, Braconidæ, Proctotrypidæ, and Cynipidæ, especially of *Microgaster connexus*, *Mesochorus pallidus*, and *Aphidius* sp.

2. *Microgaster connexus* (Nees) is a Braconid parasite on the larvæ of the moth *Porthesia similis*.

3. *Mesochorus pallidus* (Brisch.) is a hyperparasite on the larvæ of *Microgaster* which live inside the larvæ of the moth *Porthesia similis*.

4. Notes and descriptions of part of the life-history of *Apanteles glomeratus*, allied to *M. connexus*, are also given.

5. *Microgaster* lays from sixteen to fifty eggs inside the body of small larvæ of *Porthesia similis*. In rare cases very few eggs are laid, while in other examples sixty larvæ were bred from one parasitized moth caterpillar. Average number about thirty.

6. The anatomy of the larvæ is described. My account of brain, tracheal system, gonads, silk glands, and gut broadly agrees with that of Seurat.

7. Two tubes, called enigmatic tubular glands, are attached to the vesicle near the gut and pass up the body forwards. They do not, as described by Seurat, connect with the hind region of the gut.

8. The heart is described; it opens into the last segment of the body, where it is very wide.

9. The last abdominal "segment" is expanded into an enormous vesicle, whose structure and minute histology is described.

10. Two coiled tubes in the vesicle, described for the first time, appear to be excretory in nature.

11. No Malpighian tubes were found, but it was thought that the enigmatic tubular glands might be modified Malpighian tubes (see pages 411-412).

12. The gut and fat-absorption are described. The presence of food in the gut is demonstrated clearly.

13. The hyperparasite has been shown to oviposit, while the larval *Microgaster* is from one-third to one-half full size.

14. Certain facts with regard to the habits of the hyperparasite *Mesochorus* are given.

15. Notes are given on Parasitism and Hyperparasitism among Aphidæ.

16. Figures of four insects bred from Aphids, and belonging to different Families, are given.

17. The presence of a peculiar embryonic membrane in *Aphidius* sp. parasitic on *Aphis pomi* is described, and its use pointed out.

18. The subject of Entomophagous Parasitism in Hymenoptera is fully discussed from the point of view of Microgasteridæ and Aphidiidæ.

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EXPLANATION OF THE PLATES.

LETTERING.

- | | |
|---|---|
| <i>A.</i> Mass of large embryonic cells, probably part of an embryonic membrane (inner membrane, amnion?). | <i>L.</i> Carcase of the caterpillar of <i>Porthesia similis</i> after exit of the parasites. |
| <i>BM.</i> Buccal mass, mouth-parts, etc. | <i>M.</i> Mouth. |
| <i>BR.</i> Brain. | <i>MP. & MN.</i> Mesenteron of hyperparasite. |
| <i>BR.P.</i> Brain of hyperparasite. | <i>MT.3.</i> Metathorax. |
| <i>C.</i> Cocoons of parasitic <i>Microgaster</i> s after they have left the host's body. | <i>MU.</i> Muscle. |
| <i>C.O.R.</i> Cornicle of <i>Aphis</i> . | <i>NC.</i> Nerve-cord. |
| <i>CP.</i> Cell-process. | <i>NY.</i> Last segment of nerve-cord. |
| <i>CSG.</i> or <i>CD.</i> Common salivary (silk) duct, the meeting of the two pairs of glands (<i>SG</i>) being at <i>X</i> . | <i>O.</i> Opening of vesicle gland. |
| <i>CT.</i> Connective-tissue cell. | <i>OC.</i> Outer chitinous layer or cuticle. |
| <i>D.</i> Dorsal. | <i>P.</i> Parasite inside host. |
| <i>F.</i> Fæcal mass left by larval insect before pupation. | <i>PT.2.</i> Prothorax. |
| <i>F.B.</i> Fat-body. | <i>R.</i> Rectal region. |
| <i>F.E.</i> Frilled edge of cell. | <i>S.</i> Outer embryonic membrane (serosa?). |
| <i>G.</i> Gonad. | <i>1st S., 7th S.</i> First and seventh stigmata. |
| <i>GL.</i> Vesicle gland. | <i>SA.</i> Pseudo-amnion or embryonic membrane. |
| <i>GLX.</i> Granular area. | <i>SG.</i> Silk (salivary) gland. |
| <i>GT.</i> Gut. | <i>SH.</i> Sheath of ovipositor. |
| <i>H.</i> Heart. | <i>SP.</i> Space between edges of cells. |
| <i>HD.</i> Head. | <i>ST.</i> Stomach. |
| <i>HP.</i> Hyperparasite. | <i>STIL.*</i> Stylets of ovipositor. |
| <i>HY.</i> Hypoderm. | <i>Tx.</i> Enigmatic tubular gland (Malpighian tube?). |
| <i>IDA.</i> Imaginal disc of antennæ. | <i>T.R.</i> Tracheal tube. |
| <i>ID1, ID2, ID3.</i> Imaginal discs of legs. | <i>T.V.</i> Terminal vesicle. |
| | <i>V.</i> Ventral. |
| | <i>W¹ & W².</i> Imaginal discs of wings. |

PLATE 24.

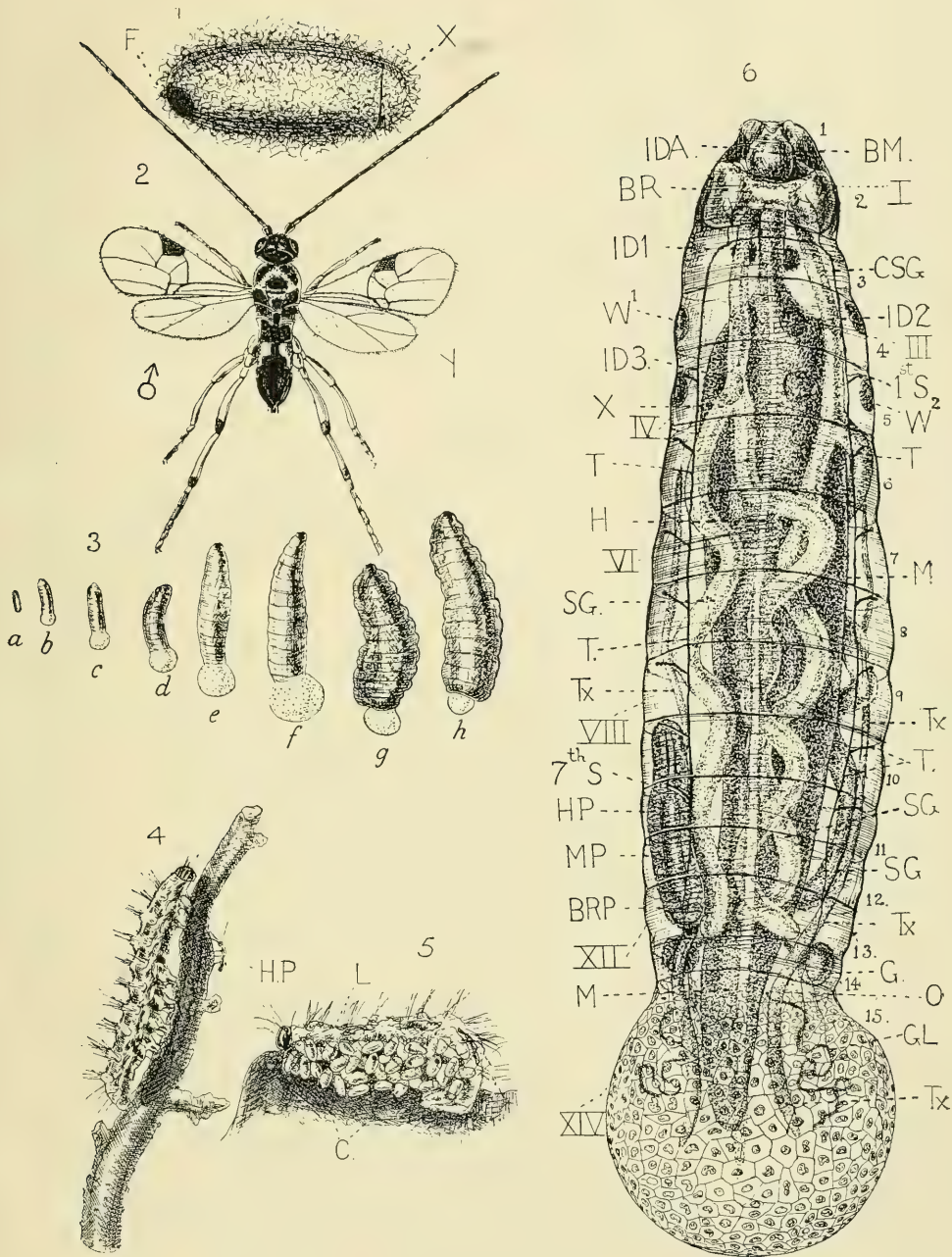
- Fig. 1. *Microgaster connexus* cocoon after emergence of imago. The latter has made its exit by cutting a beautiful lid (*X*). Compare fig. 9. $\times 8$.
- Fig. 2. *Microgaster connexus* (Nees), adult male. $\times 8$.
- Fig. 3. Outlines of larvæ of *M. connexus* drawn at different ages, *a—h*, at same scale as previous figures.
- Fig. 4. Adult *Porthesia similis* larva, with hyperparasitic *Mesochorus pallidus* (Brisch.) at *HP.* drawn to same scale as caterpillar. $\times 1$.
- Fig. 5. Parasitized caterpillar's skin after emergence of parasitic *M. connexus*. The latter larvæ have spun their cocoons at *C.* $\times 1$.
- Fig. 6. Somewhat diagrammatic drawing of the complete anatomy of the three-quarter grown larva of *M. connexus*. Hyperparasite at *HP.* The tracheal system rather schematic, everything else except heart drawn to scale. The secondary branches of the tracheal system were not put in, so as to leave the drawing clearer. The heart in the hind region should be wider, but it has not been put in so, in order to show the gut better. $\times 45$.

PLATE 25.

- Fig. 7. The Hyperparasite, *Mesochorus pallidus* (Brisch.), adult male. $\times 8$.
- Fig. 8. Ovipositor showing terminal region of body, ovipositor sheath (*SH.*) and stylets (*STIL.*).
- Fig. 9. Cocoon of *Microgaster connexus* which had been hyperparasitized by *Mesochorus pallidus*, and from which the latter had emerged by making a rough hole at *X*. At *F* is the faecal pellet voided by the larva before pupation; it will be noticed that the faecal pellet in fig. 9 is larger than that in fig. 1. $\times 8$.
- Fig. 10. Terminal abdominal region drawn from a larva preserved in an osmic-acid fixative. The fat is blackened. At *HP. HP.* the hyperparasite is cut across in two places. The two transverse sections have been schematically joined together by lines behind the gut, as the hyperparasitic larva was bent around the gut in the form of a half-circle. The enigmatic tubular glands (Malpighian tubes) were not cut in this obliquely sagittal section, but the left-hand one has been drawn in diagrammatically at *Tr.* $\times 60$.
- Fig. 11. Transverse section of metathorax showing hyperparasite at *HP*, *X*. The last pair of imaginal discs of the legs are cut at *ID3*. $\times 70$.
- Fig. 12. Four cells of the terminal vesicle drawn from such a part as that enclosed by a square in fig. 10. $\times 510$. (Fixed in $K_2Cr_2O_7$ of 3 per cent.)
- Fig. 13. Hypoderm of body-wall. $\times 510$.
- Fig. 14. Vesicle cells fixed in alcohol-acetic-acid fixative. $\times 300$.

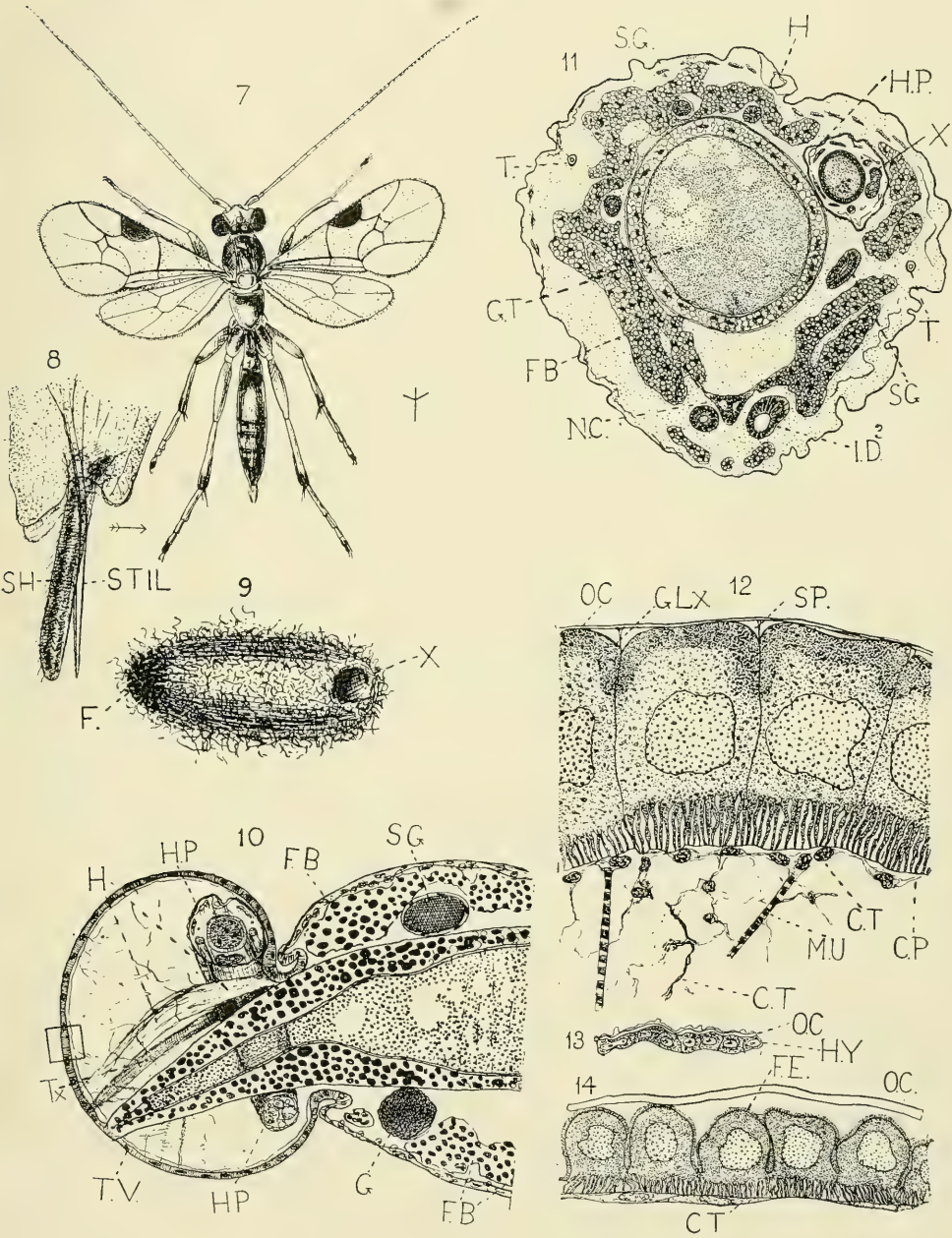
PLATE 26.

- Fig. 15. Three-quarter grown *Aphis pomi*, whole preparation (paracarmine); shows parasitic larva (*Aphidius* sp.) at *P*, in optical section. Below is drawn the upper (tail) region of the parasitic cyst, to show the embryonic membrane (*SA*). $\times 60$.
- Fig. 16. Very young larva of *Microgaster connexus* showing embryonic membranes at *S* and at *A*. $\times 222$.
- Figs. 17 & 18. Two diagrammatic drawings illustrating the manner in which certain Braconids (Aphidiidae) attack Aphids. In fig. 17 the abdomen of the Aphid faces the observer and the parasite is attacking from the side. In fig. 18 it is attacking from the back, the usual way.
- Fig. 19. High-power drawing of the region *X* in fig. 20. Below is the heart (*H*), at *GL* is the opening of the vesicle gland. Dorsal surface of body to the right, ventral to the left. $\times 300$.
- Fig. 20. Gives the key to the position of the drawing in fig. 19. See text, p. 398.
- Fig. 21. Transverse section of vesicle gland. $\times 510$.
- Fig. 22. Transverse section of posterior region of vesicle, showing enigmatic tubular gland (Malpighian tube?) at *Tr*, vesicle glands at *GL*, and heart at *H*. $\times 95$.
- Fig. 23. Part of the transverse section of the enigmatic tubular gland (in fig. 22 at *Tr*) drawn at a high power. $\times 510$.
- Fig. 24. Schematic figure of structure of half-grown larva of *Microgaster* to show nerve-cord ending near *NY*, and the disposition of the other organs.
- Fig. 25. Young larva of *M. connexus* showing the arrangement of the later embryonic organs, the segmentation, the embryonic membranes (*S* & *A*), and the vesicle in an early stage. $\times 95$.



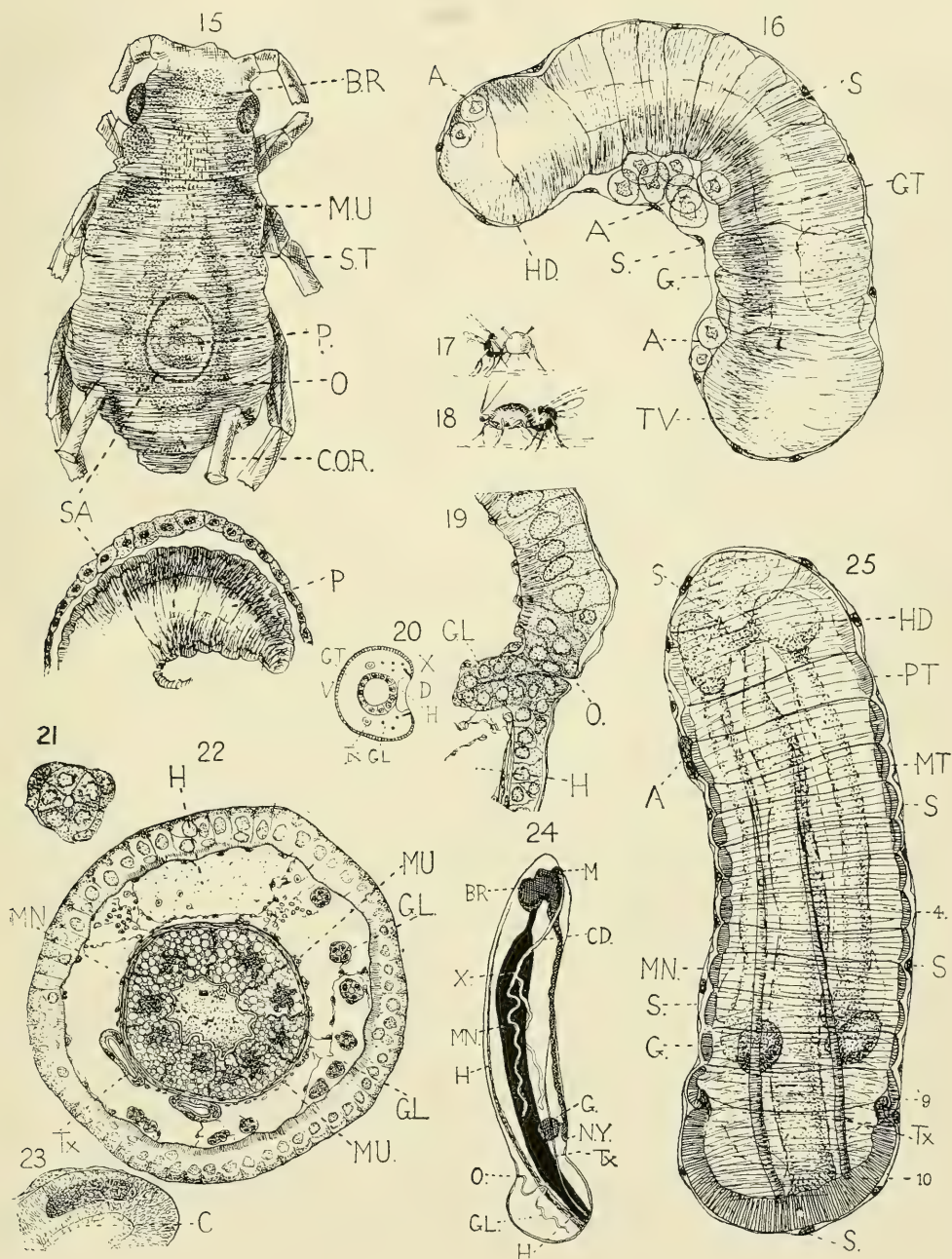
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MICROGASTER AND HYPERPARASITE.



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MICROGASTER AND APHIDIUS.

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[Synonyms and native names are printed in *italics*. A star * denotes the first publication of a name, a dagger † a fossil species.]

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